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THE EFFECT OF HARVESTING PRACTICES ON YIELD AND WINTER SURVIVAL OF ALFALFA UNDER IRRIGATION[1]

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Under irrigated conditions in Western Canada, the recommended harvesting practice for alfalfa is two cuttings per season at the one-tenth to one-quarter bloom stage. These recommendations are not always followed by growers. In some instances, three cuttings are attempted, but it is difficult to remove the third crop early enough to allow much fall growth before winter. Where only two cuttings are taken, these are frequently harvested at an advanced stage of growth which results in poor quality hay and again does not permit much regrowth in the fall. Under the rigorous winter conditions prevailing in the area, observations suggest that much winterkilling in alfalfa is the result of improper harvesting practices, even where diseases such as winter crown rot and bacterial wilt are held directly responsible for winter losses.

The study reported in this paper was undertaken to compare crude protein and hay yields of Grimm alfalfa grown under irrigation when harvesting was done at three stages of growth throughout the season, and also to find out how these cutting treatments affected winter survival and vigour.

LITERATURE REVIEW

The importance of alfalfa as a forage crop has led to numerous investigations dealing with management practices, especially with harvesting schedules to obtain high yields of quality feed and at the same time maintain productive stands. In Kansas, Grandfield (5) found that winter protection aided materially in maintaining stands of Kansas Common or Grimm. When cut throughout the season at the bud stage, depletion of stands resulted. In a subsequent study, Grandfield (6) considered autumn to be the critical period in relation to harvesting practices, organic food reserves and permanence of the stand. Early and frequent cutting at the bud stage resulted in lower carbohydrate and nitrogen content of the roots when winter arrived. In Iowa, Mark (7) found that cutting Grimm alfalfa in late August and early September prevented the normal fall accumulation of reserve proteins and carbohydrates and severe winterkilling resulted. In Germany, Bär and Tseretheli (2), studying the effect of clipping treatments on alfalfa grown in boxes, concluded that two cuttings per season allowed the best root development and insured plenty of food reserves for good growth the following year. Only one-fifth as much root reserves were

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stored through frequent cutting as when only cut twice in a season. Brown and Munsell (3) in Connecticut found that three cuttings per season produced larger total yields than two, but if this practice was followed for two successive years, reduction in stand occurred. After removal of top growth, root carbohydrates decrease markedly. Low carbohydrate content in the fall, as a result of cutting at this time, was related to winter mortality. In New Jersey, studies by Dotzenko and Ahlgren (4) showed that frequent and early cutting of alfalfa in a brome grass-alfalfa mixture reduced the weight of alfalfa roots, the percentage of total polysaccharides in the roots, and lowered yields the following year.

MATERIALS AND METHODS

In 1948, plots were laid out on a stand of irrigated Grimm alfalfa which had been seeded in 1944. The experiment was located on an alluvial Fox Valley clay loam soil. Treatments consisted of cutting at the bud, early flowering, and late flowering stages of growth. These treatments were replicated six times in a randomized block design. The plots measured 6 feet wide and 20 feet long.

The plants were considered to be in the bud stage when a high proportion of buds were showing, but before any flowers had opened. The early flowering stage corresponded to 10 to 25 per cent in bloom, and the late flowering stage to 100 per cent in bloom. Harvesting at designated stages of growth was done by cutting a 4-foot swath through the centre of each plot with a power mower after first removing the end borders. The cut

TABLE 1.—HAY AND CRUDE PROTEIN YIELDS AND PERCENTAGE CRUDE PROTEIN CONTENT—1948

Yields and Crude Protein Content by Cuttings	Stage of Growth When Harvested			Least Sig. Dif.
	Bud	Early Flowering	Late Flowering	
First Cutting				
Date cut	June 15	June 25	July 7	
Hay yield in tons per acre	2.43	2.73	3.07	0.27*
Per cent protein	19.00	18.24	14.76	1.35*
Protein yield in pounds per acre	826	888	810	Nil
Second Cutting				
Date cut	July 26	August 10	Sept. 2	
Hay yield in tons per acre	1.76	1.93	2.11	Nil
Per cent protein	20.52	19.83	17.30	1.42*
Protein yield in pounds per acre	642	686	654	Nil
Third Cutting				
Date cut	Sept. 2			
Hay yield in tons per acre	1.30			
Per cent protein	22.00			
Protein yield in pounds per acre	508			
Total for Cuttings				
Hay yield in tons per acre	5.49	4.66	5.18	0.41*
Protein yield in pounds per acre	1976	1574	1464	168*

* Significant at the 1 per cent level.

material was raked up immediately, weighed, and a two-pound sample taken for dry matter determination. After oven drying and weighing, this sample was ground finely and a sub-sample analysed for total nitrogen by the Kjeldahl Method (1). Total nitrogen in per cent was multiplied by the factor 6.25 to give crude protein content in per cent. Crude protein yields per acre were calculated by multiplying percentage crude protein times oven dry hay weights. Hay yields per acre were calculated on a 12 per cent moisture basis.

In 1948 and 1949, the bud stage plots were cut three times, the early and late flowering stage plots twice. In 1949, observational notes were recorded on vigour and winter injury on all plots. No yields were taken in 1950 because stands were markedly reduced following early spring flooding and ice conditions. However, a visual estimate of the stand on each plot was made.

RESULTS AND DISCUSSION

The 1948 data presented in Table 1 show that three cuttings at the bud stage produced higher yields of hay and crude protein than two cuttings at the early flowering stage. Two cuttings at the late flowering stage also resulted in a higher yield of hay than two at the early flowering stage and nearly the same yield on crude protein. Thus, the 1948 results indicated that cutting alfalfa three times at the bud stage of growth would produce the highest yield and highest quality feed, and also that two cuttings at the late flowering stage would give higher hay yields and nearly as much crude protein as two cuttings at the early flowering stage.

TABLE 2.—HAY AND CRUDE PROTEIN YIELDS AND PERCENTAGE CRUDE PROTEIN CONTENT—1949

Yields and Crude Protein Content by Cuttings	Stage of Growth When Harvested			Least Sig. Dif.
	Bud	Early Flowering	Late Flowering	
First Cutting				
Date cut	June 20	June 28	July 20	
Hay yield in tons per acre	1.21	2.79	1.78	0.27**
Per cent protein	23.32	16.94	17.37	1.38**
Protein yield in pounds per acre	502	846	553	100**
Second Cutting				
Date cut	July 28	August 10	Sept. 2	
Hay yield in tons per acre	1.08	1.46	1.34	0.13**
Per cent protein	21.89	19.19	19.34	1.21**
Protein yield in pounds per acre	420	496	460	Nil
Third Cutting				
Date cut	Sept. 2			
Hay yield in tons per acre	0.69			
Per cent protein	20.17			
Protein yield in pounds per acre	253			
Total for Cuttings				
Hay yield in tons per acre	2.98	4.25	3.12	0.35**
Protein yield in pounds per acre	1175	1342	1013	100**

** Significant at the 1 per cent level.

TABLE 3.—HAY AND CRUDE PROTEIN YIELDS—1948 AND 1949

Stage of Cutting	Hay Yield In Tons Per Acre			Protein Yield In Pounds Per Acre		
	1948	1949	Total	1948	1949	Total
Bud	5.49	2.98	8.47	1976	1175	3251
Early Flowering	4.66	4.25	8.91	1574	1342	2916
Late Flowering	5.18	3.12	8.30	1464	1013	2477
Least Sig. Dif.	0.41	0.35	Nil	168	100	208

ANALYSIS OF VARIANCE

Source of Variation	Degrees of Freedom	F Values	
		Hay Yields	Protein Yields
Stages	2	2.50	22.00
Years	1	242.90*	272.00*
Years × Stages	2	35.80*	31.00*

* Significant at the 1 per cent level.

It should be noted that the second cutting at the late flowering stage and third cutting at the bud stage in 1948 were harvested on September 2, while the second cutting at the early flowering stage was harvested on August 10. These dates of last cutting had a decided influence on yield, vigour, and winter survival the following season. In 1949, alfalfa on the bud stage and late flowering stage plots was much less vigorous growing than on the early flowering stage plots, and the stands were noticeably thinner. Of these two treatments, alfalfa on the bud stage plots was less vigorous and suffered a slightly greater reduction in stand. No evidence of winter injury could be seen on any of the early flowering stage plots. The data for 1949, presented in Table 2, show how the 1948 cutting treatments affected yields. The total yield of hay and crude protein in 1949 from the bud and late flowering stage plots was considerably below that obtained from the early flowering stage of cutting plots.

The total yields for the 2-year period and the analysis of variance are reported in Table 3. Total hay yields did not vary significantly between stages of cutting, but the total protein yields differed significantly from each other. The highest protein yield was obtained by harvesting at the bud stage and the lowest at the late flowering stage. The large F values for years bears out that the average yield of hay and protein for the three stages of cutting was significantly higher in 1948 than in 1949. The significant F value for the interaction of years and stages indicates stage of cutting affected hay yields differently each year; the same is true of protein yields. The data show that harvesting at the bud stage gave a high yield in 1948 and a low yield in 1949, illustrating the detrimental effect of two frequent cutting on production the following year. Yields from the late flowering stage of cutting follow the same trend and bring out the fact that cutting too late also seriously affects subsequent yields.

When cut twice per season at the early flowering stage for two consecutive years, alfalfa produced as much hay and only slightly less crude protein than did three cuttings at the bud stage. Cutting at this stage of growth also resulted in an equivalent hay yield and a higher crude protein yield than was obtained by two cuttings at the late flowering stage. Although the experiment was not designed to study cost of production, it is obvious that two cuttings at the early flowering stage would be the most economical harvesting procedure to follow. In addition, cutting at this stage of growth did not appear to reduce vigour of the plants nor did any noticeable winter injury occur.

In the early spring of 1950, the experiment became flooded when warm weather caused sudden melting of snow. It was impossible to drain the water off for about two weeks and much of this time it was frozen solid. These severe conditions likely caused more injury to the alfalfa than would have occurred otherwise. Later in the season, visual estimates of the remaining stand on each plot were made. It was found that the alfalfa on five of the bud stage plots was completely killed out, the sixth plot having a 75 per cent stand remaining. In the late flowering stage treatment, alfalfa on two of the plots was completely killed out. The average stand including these two plots was estimated at 15 per cent. None of the early flowering stage plots was entirely killed out, the lowest stand estimation being 25 per cent, and the average stand of alfalfa on the six plots was approximately 60 per cent.

This investigation brings out several important facts in relation to management of alfalfa under irrigation in Western Canada:

1. The results indicate that three cuttings per season will give higher yields of hay and protein during the first year than two cuttings, but these gains will be offset by lower yields and reduction in stand the following year.
2. If only two cuttings are harvested, but cutting is done at an advanced stage of growth, reduction in stand and yield also will occur the following year. Cutting too late is nearly as destructive as cutting too frequently.
3. Over a 2-year period, two cuttings per season at the early flowering stage will likely produce hay yields equal to or higher than three cuttings, and a protein yield only slightly less. In addition, productive stands will be maintained in the third year.
4. Costs of production per unit of feed would be lowest when only two cuttings at the early flowering stage were harvested.
5. The results suggest that the date of last cutting of alfalfa should be prior to September 2 under similar climatic conditions if winter injury is to be avoided. Cutting as late as September 2 apparently does not allow the plants to make sufficient regrowth to build up adequate root reserves before winter.

These conclusions are in close agreement with those obtained by several investigators in other regions, (3), (4), (5), (6), and (7).

SUMMARY

An experiment with Grimm alfalfa (*Medicago media* Pers.) was undertaken to determine a desirable type of harvesting practice to follow under irrigated conditions in Western Canada. The first year, three cuttings at the bud stage of growth resulted in a higher yield of hay and crude protein than two cuttings at the early flowering or late flowering stage. The following year, when the same cutting treatments were employed on the same plots, yields from the bud and late flowering stage treatments were significantly less than from the early flowering cutting treatment. In

addition, the stand of alfalfa was thinned over winter and reduced in vigour by cutting at the bud and late flowering stage. For the 2-year period, two cuttings per season at the early flowering stage produced a hay yield equal to and a protein yield slightly less than was obtained by cutting three times at the bud stage of growth. Satisfactory stands were maintained when cutting was done at the early flowering stage, but were reduced by the second year and seriously depleted in the third year following cutting at the bud and late flowering stage. The results indicate the last date of cutting alfalfa should be before September 2 to avoid winter injury. It was concluded that the most economical cost of producing alfalfa hay would be when two cuttings per season were harvested at the early flowering stage of growth.

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STUDIES ON HUMUS TYPE LEGUME INOCULANTS[1,2]

I. GROWTH AND SURVIVAL IN STORAGE

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INTRODUCTION

Since 1905, the Department of Bacteriology, Ontario Agricultural College, has produced and distributed large numbers of legume inoculants to farmers not only in Ontario, but in other provinces if requested.

These inoculants have been pure cultures of single strains of rhizobia on agar slopes. This has largely been because of the belief that fresh, virulent cultures of this type were the most beneficial.

Of recent years frequent requests have been received for what are commonly known as "Dry" or "Powdered" inoculants. Large numbers of these are manufactured and distributed annually in both Canada and the United States. With the exception of the annual reports from the U.S. Department of Agriculture, and reports from several State departments of agriculture, little has been published regarding their worth, and even less concerning the method of their manufacture.

In view of the continual requests from farmers and agricultural representatives for both humus inoculants (as they are easier to use), and for advice as to their real worth, the work herein reported was undertaken.

Powdered legume inoculants are usually prepared commercially by developing a heavy suspension of pure root-nodule bacteria in aerated liquid nutrients in protected tanks. When at the right stage of growth the suspension is withdrawn and mixed thoroughly with neutralized peat powder. Prepared in this manner inoculants are not pure cultures, but the presence of other organisms does not seem to affect their efficiency (6).

Hedlin and Newton (4) have shown greater longevity of rhizobia in sterilized humus carriers resulting from the addition of a nutrient salts mixture and the use of containers to which air had free access.

Lochhead and Thexton (7) have proposed that the high adsorptive capacity of peat, and related materials, for by-products of microbial growth suggests their value, not only as carriers proper, but as media for development of the inoculated bacteria.

MATERIALS AND METHODS

Organisms, Carriers and Nutrients

In the present work single strain cultures of *Rhizobium meliloti* and *Rhizobium trifolii* were used in combination with two carriers. No. 1, a high-lime peat, had been put through a hammermill and a fine sieve. Since this material, as received, had a moisture content of approximately 50 per cent it was air- and oven-dried to a moisture content of 20 per cent. No. 2 was composed of dried peat as in No. 1, to which was added 10 per cent by weight of No. 80 mesh powdered charcoal. Both carriers, before use, were

[1] Contribution from the Department of Bacteriology, Ontario Agricultural College, Guelph, Ontario.
[2] Part of the program of the Legume Research Committee in Ontario.

sterilized for 1 hour in the autoclave at 15 lb.-pressure in shallow layers in trays. This treatment was found by preliminary experiment to be satisfactory.

Nutrients were added to the carriers in the form of solutions, on the assumption that more even distribution should result than from the addition of a dry salts mixture in the manner of Hedlin and Newton. The composition of Nutrient Solution No. 1 was a modification of Fred and Waksman's (3) yeast-extract-mannitol agar, substituting sucrose for mannitol, Bacto-yeast extract (1.0 gm. per litre) for yeast water, and leaving out agar. This is similar, but not identical, to the salts mixture of Hedlin and Newton. Nutrient Solution No. 2 was the calcium gluconate-sauerkraut juice medium of Albrecht and McCalla (1) minus hardwood ash extract.

Inoculants were prepared at two levels of moisture—approximately 30 per cent and 50 per cent of the water-holding capacities of the carriers.

Growth of Inoculum and Mixing

Growth of the organisms to be mixed with the carriers was effected in aerated culture, in 1-litre Erlenmeyer flasks containing 600 ml. of the medium which, with addition of agar, has been routinely utilized by this Department in propagating members of the rhizobia for a number of years. Incubation was at room temperature for five days, this combination having produced maximum growth in preliminary experiments.

Mixing of the inoculants was accomplished as follows: To a previously sterilized mixer, built for this purpose, was added the necessary amount of sterilized carrier. The inoculum, consisting of 300 ml. of the broth culture, was mixed with sufficient nutrient solution that together they supplied the requisite moisture content, and the combination poured into the mixer. Mixing of the carrier and inoculum-nutrient was carried on until visual inspection indicated thorough combination.

Containers and Storage

The material, after mixing, was dispensed into two types of container: No. 1, ½–pint round "Tripletite" paint-cans, made of .25 electrolytic tinplate; No. 2, ½–pint "Perga" containers closed by the application, with a hand sealer, of metal seals heated to a red-heat in a Bunsen flame. The former were autoclaved before filling; but as the latter are made of waxed paper, they were used as received.

Approximately 100 gm. of inoculant were dispensed to each container, measured by bringing container and contents to a definite weight.

Storage of one series of inoculants was at room temperature, with a second in the refrigerator at approximately 5° C., the latter receiving a preliminary storage at room temperature for 24 hours to permit initial increase.

Sixteen lots of inoculants were made up, incorporating the four variables: organisms, carriers, nutrient solutions and moisture levels. Each lot was of such a size as to permit dispensing into a sufficient number of cans and waxed paper containers so that three of each type would be available from each storage temperature, for monthly enumeration of viable organisms.

Enumeration of Organisms

Enumeration of viable organisms was by the colony count method, using roll tubes (8) in place of Petri plates, with the regular agar, referred to above, modified by addition of 10 ml. per litre of aqueous solution of Congo Red. The latter was to help demonstrate any gross contamination only, since experience has shown absorption of this dye to be a rather doubtful criterion in the differentiation of rhizobia from many other organisms. Counts are reported as the average of the logarithms of the mean count obtained from triplicate tubes. In some instances the mean count was taken from two rather than three tubes, having regard for the observation of Wilson and Kullman (9) that, in enumerating rhizobia, if three or more plates are made in parallel, the elimination of any one plate that is markedly different from its replicates can be made without bias.

RESULTS

Moisture Levels

From the first month many of the inoculants containing moisture to the extent of 30 per cent of the water-holding capacity of the carrier were found to contain large numbers of moulds which no doubt had gained entrance from air contamination during packaging. This made it almost impossible to enumerate the bacteria, and after two months all these inoculants were abandoned and nor further counts made. No such trouble was encountered with those containing 50 per cent of the water-holding capacity of the carrier.

Containers

The inoculants in the waxed containers stored at room temperature lost moisture quite rapidly. At the end of three months losses of 20 to 35 gm. per container were noted. Those stored in the refrigerator showed very much smaller losses. The numbers of viable organisms per gm. of inoculants were not, in most cases, very different from those in the corresponding metal can; but it was obvious that the total number of organisms per waxed container was less.

At about three months after preparation a number of these waxed paper containers began to disintegrate as the result of moulds attacking the paper. In view of these drawbacks this type of container was considered to be impractical and no further counts were made. For these reasons, too, no detailed discussion of the counts which had been made is presented.

The cans used, although tightly friction sealed, provided satisfactory conditions for growth as evidenced by the results presented. This is not in accord with the results of Hedlin and Newton (4) who found that all inoculants stored in closed containers, except those prepared with black soil, gave counts lower than one million per gm. after 38 days.

Temperature

The mean logarithm of the counts per gm. for all inoculants containing 50 per cent of the water-holding capacity of the carrier stored in cans is shown in Figure 1. As might be expected, these curves show a large initial increase, which is followed by a gradual decrease in the numbers of viable organisms. Figures 2 and 3 reveal that there are variations from this

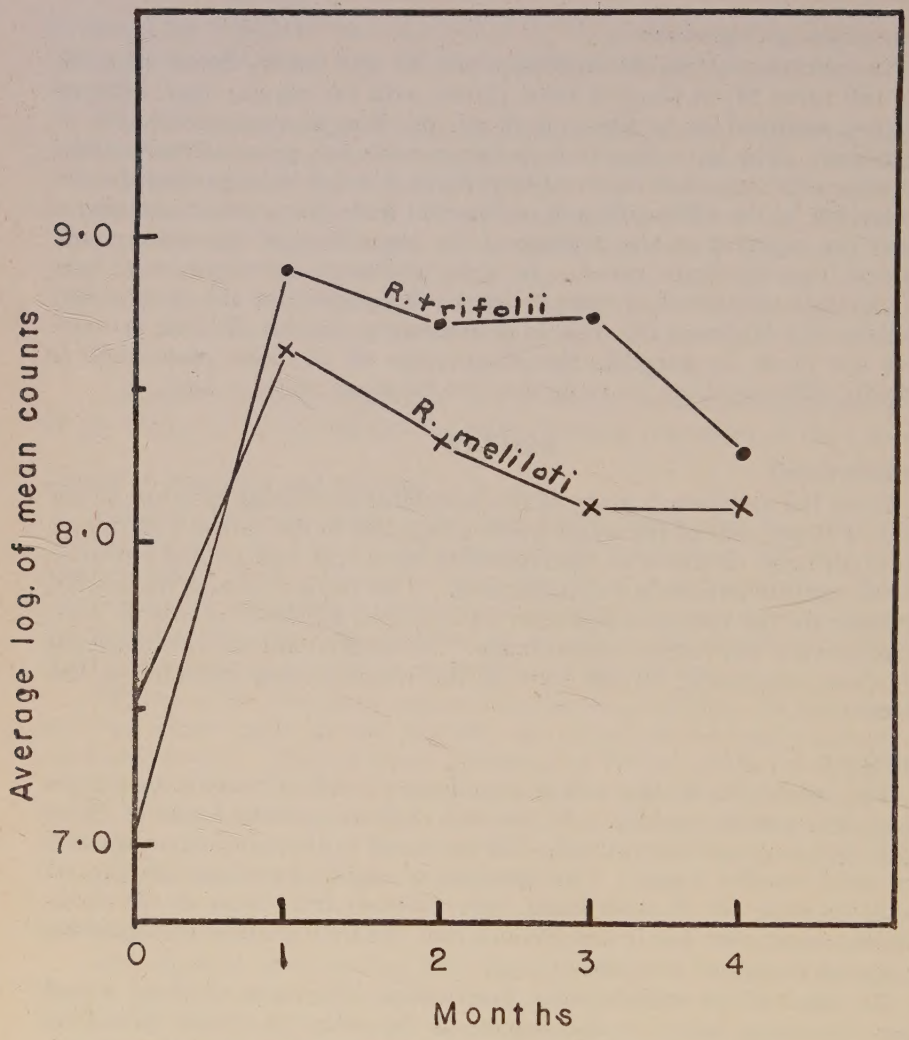

FIGURE 1. Effect of storage on viable counts of *Rhizobium meliloti* and *Rhizobium trifolii*. Mean of all inoculants in humus carriers containing 50 per cent of their water-holding capacities stored in cans.

general trend, possibly the most conspicuous of which is the result of storage temperature. It is seen that, although variation in the counts occurs as the result of both nutrient solutions and carriers, the highest counts at the end of four months' storage were obtained in inoculants stored in the refrigerator. In those containing *Rhizobium trifolii* there is not as wide variation nor as high a final count as shown by *Rhizobium meliloti* which gave the highest logarithmic average count, 2590 millions per gm., after four months' storage in the refrigerator.

Carriers

The curves in Figure 2 show that there is a wide variation in viable counts per gm. of *Rhizobium meliloti* in the two carriers. This is more apparent in those inoculants stored in the refrigerator where peat and

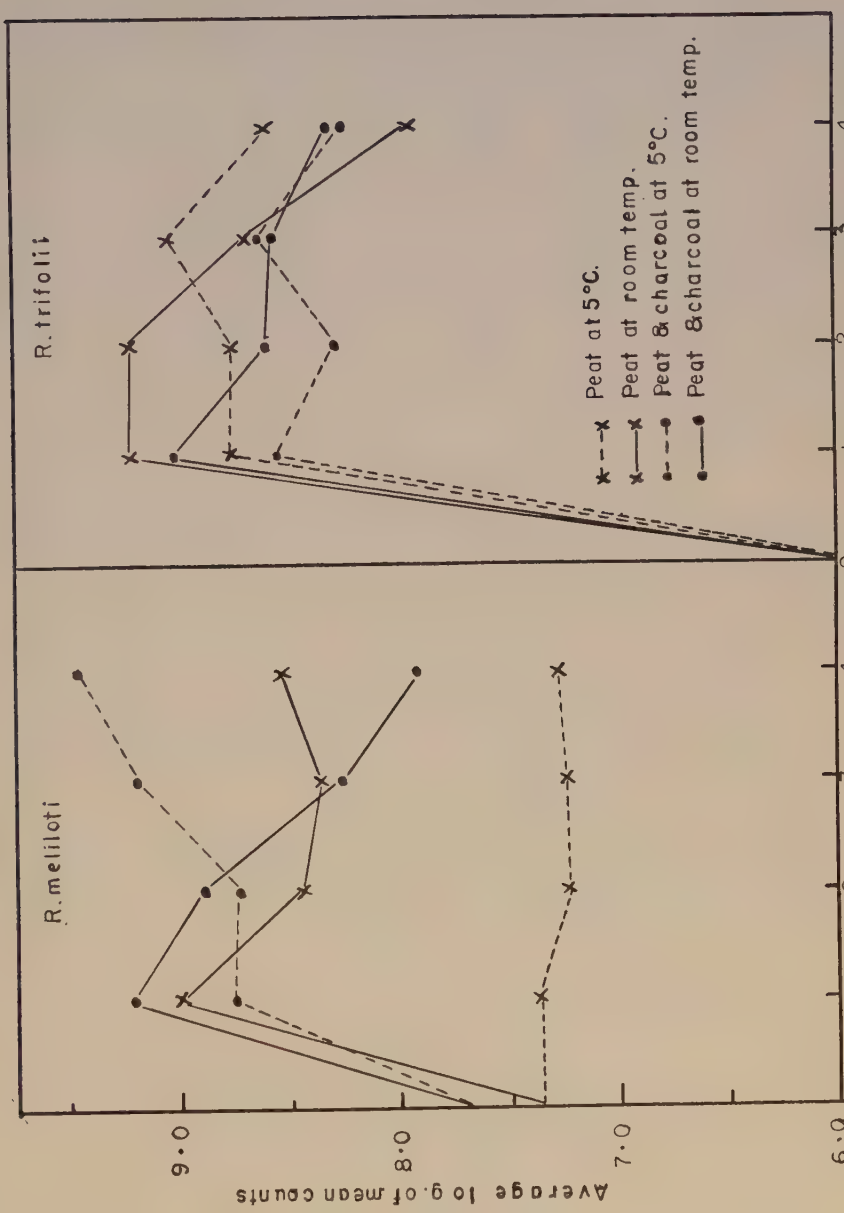

FIGURE 2. Effect of carrier on viable counts of *Rhizobium meliloti* and *Rhizobium trifolii* at two storage temperatures.

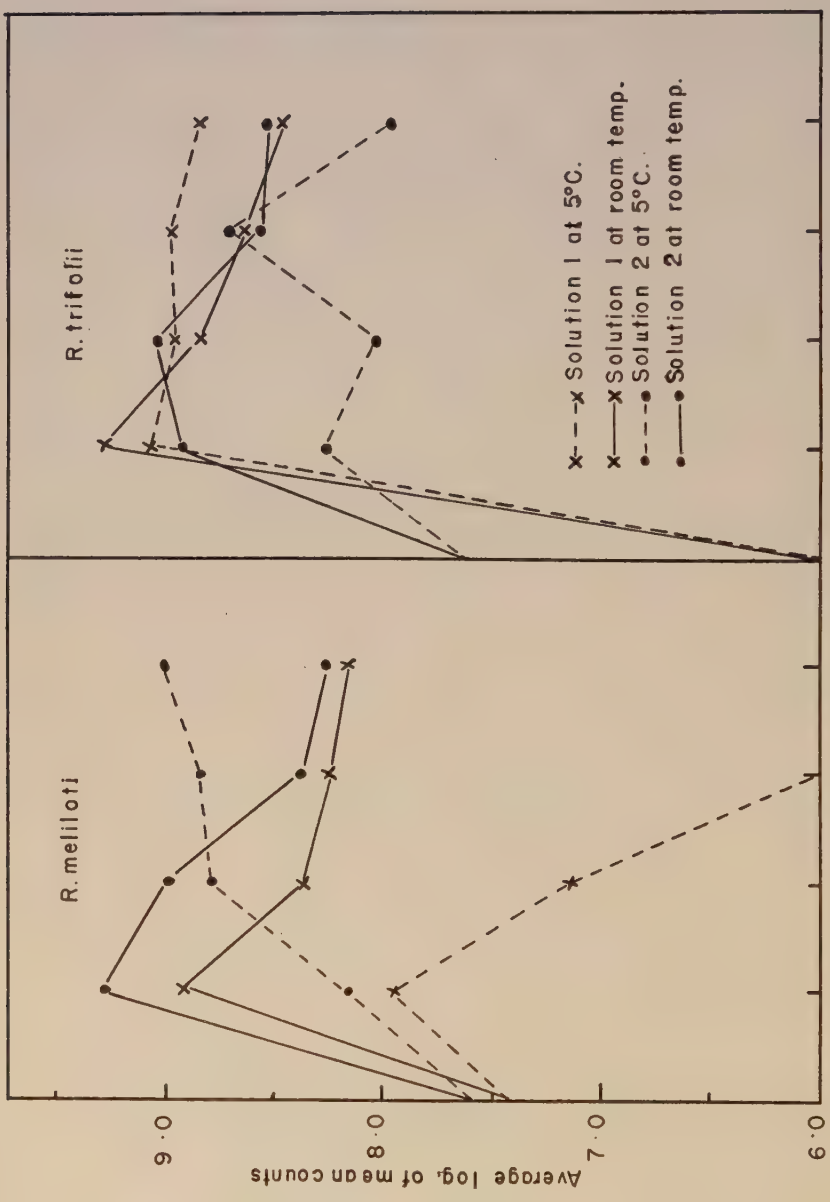

FIGURE 3. Effect of nutrient solution on viable counts of *Rhizobium meliloti* and *Rhizobium trifolii* at two storage temperatures.

charcoal mixed gave very much higher counts per gm. While some variation in the counts of *Rhizobium trifolii* is shown, it would appear that the carrier is not so important a factor with this organism.

Nutrient Solutions

The effect of nutrient solutions is shown in Figure 3. Again, *Rhizobium meliloti* shows decidedly wider variation in counts per gm., and the effect seems to be related to storage temperature. At room temperature the final counts per gm. were almost identical.

SUMMARY AND CONCLUSIONS

As a result of frequent requests for humus-type legume inoculants, work was undertaken to determine the effects of certain carriers, nutrient solutions, moisture levels, storage temperatures and type of container on the survival of *Rhizobium meliloti* and *Rhizobium trifolii*.

The results presented demonstrate that it is possible by the use of suitable combinations of these factors to produce legume inoculants of the moist humus type, in which large numbers of viable rhizobia are found after four months' storage. The highest counts were obtained after storage at approximately 5° C. in friction sealed tinplate cans.

Evaluated either by the criterion used by Fellers (2) that satisfactory inoculants should contain in excess of one million viable organisms per gm., or by that of Hofer (5) that they should contain 80 million to 200 million viable organisms per lb. of seed, these inoculants would appear to be satisfactory. This is, of course, provided that their effectiveness did not suffer in storage.

No attempt has been made to evaluate these inoculants by their ability, after storage, to produce nodules and fix nitrogen. Investigation of these additional effects is now being undertaken in this Department.

ACKNOWLEDGMENT

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NOZZLE ABRASION IN ORCHARD SPRAY APPLICATORS[1]

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Recent developments in orchard spray applicators have made it essential that spray nozzles be highly resistant to abrasion and corrosion. When spraying was done by hand the operator was able to compensate to a considerable degree for variable spray output, and enlargement of the nozzle orifice did not necessarily affect uniformity of spray treatment; but the mechanical applicators now in general use have changed the situation. They operate at a constant rate of travel and with delivery of spray material from a fixed boom; consequently, they must have a fixed rate of liquid output. When 7 or more nozzles are simultaneously in operation, any enlargement of nozzle orifices increases both the rate of output and the droplet size of the spray. The result is an inferior spray job. Another important consideration is the greatly increased abrasiveness of concentrate spray liquids that contain finely divided solids compared with the dilute mixtures that were used in hand spraying.

The hydraulic concentrate sprayers now available are fitted with various types of nozzles. Some emit a flat (fan) spray; others emit a whirling spray. Some have stainless steel nozzle discs; others have hardened but readily corroded steel discs. Some nozzles are capable of withstanding serious abrasion for a week or more; others may be ruined in a day. Obviously, information is needed on substances that show promise for nozzle discs or nozzle tips. Because there was no available published work on the subject, experiments were undertaken at the Fruit Insects Laboratory, Summerland, to estimate resistance of several metals, plastics and ceramics to abrasion by spray concentrates. The work was not precise, but it showed that it should be possible to improve nozzle performance of concentrate sprayers and thus increase their efficiency.

MATERIALS AND SOURCES

Whirl-type Nozzle Discs (hollow cone emission)

(The first four discs were obtained from Okanagan Turbo-Sprayers Limited, Penticton, British Columbia.)

1. Reference disc: stainless steel, thickness .04 inch, orifice .040 inch, hardness Rockwell C scale, less than 0.
2. High-carbon steel: heat-treated and tempered, orifice .040 inch, hardness Rockwell C, 60.
3. Mild steel (Rockwell C, 23): carburized to a depth of .01 inch, orifice .040 inch, hardness Rockwell C, 64.
4. Hardened spring steel: orifice .040 inch hardness Rockwell C, 40.
5. WICKALOY: grade HHH, W. R. 6358, sintered tungsten carbide-cobalt, orifice .040 inch, hardness Rockwell C, 70. A. C. Wickman (Canada) Limited, Toronto, Ontario.
6. Besler D3: orifice .046 inch, hardness Rockwell C, 3. Besler Engineering Corporation, Emeryville, California.
7. Bean stamped disc: orifice .078 inch, hardness Rockwell C, less than O. Food Machinery Corporation, Bean Division, San Jose, California.

[1] Contribution No. 2798, Division of Entomology, Science Service, Department of Agriculture, Ottawa, Canada.

[2] Officer-in-Charge.

8. Bean hard centre: orifice .078 inch, hardness Rockwell C, 70. Food Machinery Corporation, Bean Division, San Jose, California.
9. Plastic: brittle, casein-type, orifice .040 inch.
10. Plastic: pliable, polyethylene, orifice .040 inch.
11. Plastic: pliable, experimental, Q-187, orifice .040 inch. Dow Chemical Company of Canada Limited, Toronto, Ontario.
12. Rubber: synthetic, No. 17438, orifice .040 inch. Goodyear Rubber Company. Toronto, Ontario.
13. Rubber: automobile inner-tube grade, orifice .040 inch.
14. Ceramic: ELLAIN, orifice .040 inch. George Bray and Company, Leeds 2, England.
15. Ceramic: PERILAIN, orifice .040 inch. George Bray and Company, Leeds 2, England.

Flat-spray-type Nozzle Tips (single-plane emission)

16. T-jet: H.S. steel, orifice 0.46 inch hardness Rockwell C, 53. Spraying Systems Incorporated, Chicago, Illinois.
17. Monarch (Hardie No. 1): orifice .059 inch hardness Rockwell C, 4. Hardie Manufacturing Company, Portland, Oregon.
18. Monarch (Hardie No. 2): hardness Rockwell C, 50, orifices .059 and .078 inch. Hardie Manufacturing Company, Portland, Oregon.

PROCEDURE

An electrically operated hydraulic pump with an output of 2.6 imperial gallons per minute at 300 p.s.i. was used in the experiments. It was fitted with a 5-gallon steel tank, a 4-nozzle spray boom, a suction-line strainer, a pressure-line strainer, and a cam-actuated quick-opening valve. In operation, the nozzles were directed into the tank and the spray liquid was pumped back upon itself for 30 minutes. The test concentrate was finely divided insecticidal-grade pyrophyllite[1], 1 pound in 1 imperial gallon of water. Two nozzles of the spray boom were fitted with stainless steel reference discs as used in the 1949 model of the Okanagan TURBO-MIST sprayer[2]; the other two carried experimental nozzle tips or discs. Brittle or pliable discs were supported by a steel backing drilled to .125 inch.

Before fitting, both faces of the nozzle discs or tips were examined microscopically at a magnification of ×40. The orifices were traced on bond paper by means of a camera lucida. Then the tracings were cut out and weighed on an analytical balance. After the test run the measurements were repeated. Abrasion was calculated as the percentage increase in weight of the paper cutouts. This procedure was followed because orifices frequently became so irregular in shape that direct measurement of diameter was out of the question.

RESULTS

The results do not give an accurate indication of resistance to abrasion because there were not sufficient samples to permit repetition of trials. Consequently, only wide differences are likely to be significant. There were several sources of error, namely, difference in type of nozzle (flat or whirl spray), variation in whirl plate construction, variation in initial size of orifice, and position of nozzle on boom. On the other hand, error in actual measurement of the orifice was reasonably small. Ten separate measurements of the same orifice gave an average deviation from the mean of ±1.7 per cent.

[1] PYRAX, A. B., Vanderbilt and Company, New York, N.Y.
[2] Okanagan Turbo Sprayers Limited, Penticton, British Columbia.

TABLE 1.—ABRASION AT NOZZLE ORIFICE AS PERCENTAGE OF ABRASION AT REFERENCE NOZZLE ORIFICE

(Average of two discs measured on both faces)

Material	% Ref. Disc Abrasion
(1) *Whirl Nozzles*	
Tungsten carbide-cobalt (WICKALOY)	0.2
Bean, hard centre	5
Rubber, inner-tube grade	7 (probably less)
Besler D-3	13
Plastic, polyethylene	16–51
Ceramic, PERILAIN	18
Bean, stamped	34
High carbon, heat-treated	39
Hardened, spring steel	42
Ceramic, ELLAIN	54
Mild steel, carburized	122
Rubber, synthetic No. 17438	237
Plastic, experimental Q187	676
Plastic, casein-type	901
(2) *Flat-Spray Nozzles*	
Monarch (Hardie) No. 2	3
T-jet, H.S. steel	11
Monarch (Hardie) No. 1	18

Results are most simply expressed in terms of percentage of reference disc abrasion. After the 30-minute test run, the mean increase in size of reference disc orifices at the inner face was 103 per cent, i.e., 2.03 times the original size; at the outer face it was 182 per cent, the average of both faces being 142 per cent.

According to Table 1, whirl nozzles seem more susceptible to abrasion than the flat-spray type. A flat-spray nozzle, Monarch-Hardie No. 1, of Rockwell C, 4 hardness, showed 3 per cent as much abrasion as the stainless steel whirl-type reference disc, whereas a much harder, high-carbon, heat-treated, whirl-type disc (Rockwell C, 60) showed 39 per cent as much abrasion as the reference disc. Presumably the abrasive action of rotating liquid concentrate at the orifice of the whirl nozzle is greater than that of the direct stream emitted by the flat-spray type. Furthermore, the sides of the orifice of a flat-spray nozzle increase in thickness as abrasion takes place. The superiority of the flat-spray nozzle in this, however, may be offset by a suspected tendency to produce larger droplets than the whirl-nozzle. Officers of the Summerland laboratory are investigating that point.

To some degree, the resistance to abrasion of steel or alloy nozzle discs corresponded with their hardness. For example, the tungsten carbide-cobalt disc WICKALOY of Rockwell C, 70 hardness apparently underwent only 0.2 per cent of the abrasion of the stainless steel reference disc (Rockwell C less than 0). That is less than the expected error in measurement. The Bean hard-centre disc had a similar hardness and may be, therefore, a carbide product. It showed 5 per cent as much abrasion as the reference

disc. The difference in degree of abrasion exhibited by these two very hard discs may have depended on difference in thickness; at the orifice the thickness of the Bean disc was about one-third that of the WICKALOY disc.

A very hard disc was obtained by carburizing mild steel of Rockwell C, 23 hardness to a surface hardness of Rockwell C, 64, but it was not more resistant to abrasion than the soft stainless steel reference disc (Rockwell C, less than O)

High-carbon, heat-treated steel, Rockwell C, 60 and hardened spring steel, Rockwell C, 40 were definitely superior to the stainless steel of the reference disc in resisting abrasion; they underwent about one-third as much wear. These metals, however, are subject to corrosion from spray liquids and are undesirable from that standpoint.

As might have been expected, high-grade rubber stood up very well to the abrasive experimental spray concentrate; indeed it compared favourably with carbide alloy; but, in addition to requiring a rigid backing plate in order to withstand pressure, rubber deteriorates in contact with oils and certain organic solvents that may occur in spray mixtures. Its performance is interesting but does not suggest practical possibilities.

Three plastics and one synthetic rubber were also examined. Only polyethylene plastic showed high resistance to abrasion. This material is pliable and behaved somewhat like rubber. It expanded slightly under the 110° F. temperature generated by the pumping process and the 250–300 p.s.i. pressure. Like rubber, it required rigid backing; it might be possible to utilize it in a spray nozzle.

The British-made ceramic nozzle discs proved interesting, particularly the one trade-named PERILAIN, which was one of the most abrasion-resistant of the substances examined. PERILAIN might be adapted for use in concentrate applicator nozzles if it can be securely attached as a small-diameter insert. Its most obvious weakness was its marked susceptibility to fracture when under pressure from the tightening of the nozzle cap.

High-carbon steel, PERILAIN and ELLAIN ceramics, and tungsten carbide-cobalt were tested for resistance to corrosion in water and in tetraethyl pyrophosphate, octamethyltetramido pyrophosphate, parathion, and lime-sulphur spray concentrates. After 13 days only the high-carbon steel had undergone measurable decrease in weight. Tetraethyl pyrophosphate was the most corrosive of these substances.

Improvement in the performance of the whirl nozzle depends on attention to the whirl plate as well as to the nozzle disc. Certain rapidly rotating spray concentrates exert a highly abrasive action at the centre of the whirl plate; they may drill a hole backwards through the plate in a matter of hours. When the break-through occurs the spray pattern is badly disrupted and the droplet size increases. Brass whirl plates are not very satisfactory; stainless steel lasts longer. Doubtless cemented tungsten carbide would be an ideal material for this purpose if the cost is not prohibitive.

SUMMARY

The recent widespread use of high-pressure concentrate sprayers in the orchards of British Columbia has raised a problem in the excessive abrasion of spray nozzles. By the use of a pyrophyllite spray concentrate, 18 materials, including some commercial spray nozzles, were examined for resistance to abrasion. Results were as follows:—

1. Flat (fan) spray nozzles seem less subject to abrasion than whirl nozzles but they may be less efficient in atomization of spray liquid.

2. The most abrasion-resistant material was tungsten carbide-cobalt (WICKALOY). It also proved highly resistant to corrosion from various spray concentrates.

3. Carburizing (case hardening) did not appear to help in reducing the abrasion of mild steel. Even exceedingly hard, high-carbon, heat-treated steel was not satisfactory. It was not sufficiently resistant either to abrasion or to corrosion.

4. High-grade rubber showed great resistance to abrasion but, because of its deterioration in oils and certain organic solvents, cannot be suggested for use in spray nozzles. A synthetic rubber proved very susceptible to abrasion.

5. The three plastics examined did not prove suitable for use in spray nozzles, but a polyethylene type was more resistant to abrasion than stainless steel.

6. A ceramic material was notably resistant to abrasion and corrosion but too subject to fracture to be fitted as a nozzle disc of the type now in use.

7. Whirl plates for concentrate sprayer nozzles should not be made of brass because of the pronounced drilling action of certain spray concentrates. Stainless steel is preferable and cemented tungsten carbide would be still better if the cost is not excessive.

ACKNOWLEDGMENTS

The writer acknowledges with thanks the assistance of the manufacturers noted in the section "Materials and Sources". They supplied nozzle tips for experiment and very kindly made discs of tungsten carbide and of two ceramics to specification. Okanagan Turbo Sprayers Limited provided information on the hardness of metals used in the trials. Also acknowledged is the ready assistance of J. M. McArthur, of the Division of Chemistry, Dominion Fruit Insects Laboratory, Summerland, B.C., in testing the performance of the laboratory sprayer and in examining the resistance to corrosion of several experimental materials.

SEEDLING SUSCEPTIBILITY OF DENT CORN INBREDS TO ROOTROT CAUSED BY *PYTHIUM ARRHENOMANES*[1]

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INTRODUCTORY

The importance of *Pythium arrhenomanes* in the corn rootrot complex has become increasingly evident in both Ontario and the United States.

Pythium arrhenomanes was reported first on corn roots by Johann, Holbert, and Dickson (4) in 1926, but they were unable to identify the species. In the same year, Valleau *et al.* (11), in Kentucky, claimed that corn rootrot was caused by a soil-inhabiting pathogen, which they reported as an undetermined species of *Pythium*. A year later Branstetter (1), in Missouri, reported similar findings. In 1928, Subramanian (9), in India, observed a *Pythium* with filamentous sporangia in decaying wheat roots and, in the same year, Drechsler (2) described *Pythium arrhenomanes*.

This pathogen apparently has a wide geographic distribution and a considerable host range, having been found causing severe rootrot on several hosts of economic importance in the United States, Canada, Hawaii and India. Edgerton, Tims, and Mills (3) have stressed the importance of *P. arrhenomanes* in the rootrot disease of sugar cane in Louisiana, and Subramanian (10) reported a similar condition in India. Sideris (8) has included pineapple along with other tropical plants as hosts of this organism. The causal agent of browning rootrot of wheat in Canada has been described and named by Vanterpool and Truscott (12) as *P. arrhenomanes* var. *canadensis*. Pathogenicity tests have shown that timothy, oats, barley, rye, and sorghum are also actively parasitized by this fungus.

Rands and Dopp (6), in 1934, reported a detailed study of 70 isolates of *P. arrhenomanes* obtained from various places and hosts throughout North America, India and Hawaii. They concluded from a comparison of morphological characters, cultural studies, and infection experiments that *P. arrhenomanes* was composed of a considerable number of variously differentiated forms.

Because of the importance of this species of *Pythium* throughout the corn-growing area of southern Ontario, as shown by Richardson (7) and McKeen (5), it has become increasingly important to obtain accurate information concerning the relative susceptibility to *Pythium* rootrot of the inbred parent lines available at the present time. The fact that a high percentage of all corn planted in Ontario is of hybrid origin renders such information particularly essential.

MATERIALS AND METHODS

All tests for resistance were conducted in constant temperature rooms, maintained at 20° C. and illuminated with fluorescent lamps of the daylight type. The seedlings were grown for 4 weeks in steamed compost soil.

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Before the soil was put in formalin-treated flats, it was thoroughly mixed with *P. arrhenomanes*-cornmeal-sand inoculum, usually at the rate of 200 cc. per cu. ft. Also, 3 naturally infested but different rootrot soils were used to test the resistance of certain inbreds.

All inbreds had been selfed at least 5 times and thus were quite homozygous. The following were used: 187-2, A, A374, H7, H8, H11, H20, Hy, LC19, M14, MS77, N6, R3, R4, R59, R61, S6-2, S6-3, S6-39, W17, W20, W22, W23, W26, W29, W32, W375, and WF9. Only healthy seed was used and it was treated with thiram previous to planting in all cases in order that surface-borne organisms would be destroyed. Forty seeds of each of the 28 inbreds were planted in one-half of each flat of inoculated soil which comprised a unit and the experiment was replicated 4 times. Concomitant with this, seeds were planted in sterile soil in order that the viability and rate of germination of the seed, and the vigour and size of individual inbred plants, could be determined. The soil was kept uniformly moist and observations were made each day.

EXPERIMENTAL RESULTS

All seed used had a germinating capacity of 90 per cent or more, and inbreds showed some variability in time of emergence though little difference in size was detected after 2 weeks of growth in compost. In the soil inoculated with *P. arrhenomanes*, all seed germinated within the same period as in the sterile compost, excepting that of H20. Evidently this pathogen was not able to influence the emergence of the seedling when the seed was protected with thiram. This finding is supported by the fact that the most susceptible inbreds frequently emerged first. The seed of H20 was extremely small and apparently did not have a large enough energy supply to push the coleoptile above the ground if the roots were destroyed.

Although some of the most susceptible inbreds emerged early and grew faster at first than the more resistant inbreds, their susceptibility could be detected 2 or 3 days after emergence. Such inbreds failed to continue growth and their dark blue-green leaves remained in a rolled, upright position.

Of 28 inbreds tested, R4 was the only one which consistently continued to grow in infested soil. The resistance of this inbred, as indicated by its continued growth in the presence of *P. arrhenomanes*, could be detected as early as 4 to 5 days after emergence of the seedlings (Figure 1). On the other hand, stunting of seedlings of all other inbreds in infested soil increased in direct proportion to their susceptibility to *P. arrhenomanes* and the time elapsing from date of sowing (Figures 2 and 3). It should also be mentioned that in steamed compost differences in growth of the various inbreds tested were negligible (Figure 4).

Regarding the determination of the relative resistance of the various inbreds to *P. arrhenomanes*, it was found that if temperatures were maintained at either too high or too low levels, either no stunting at all resulted or all seedlings were killed outright. Similar results were obtained when either too little or too much inoculum was used per unit of soil. Thus, the

FIGURE 1. Six 10-day-old inbreds growing in soil inoculated with *P. arrhenomanes*. R4 occupies the upper centre sector and is taller than the other five inbreds. FIGURE 2. The same inbreds as in Figure 1, but the plants are 15 days old. FIGURE 3. *Left*—WF9, a susceptible inbred; *right*—R4, a resistant inbred. They grew in soil inoculated with *P. arrhenomanes* for 28 days. FIGURE 4. *Left*—WF9; *right*—R4. Both inbreds are 28 days old but grew in sterile compost.

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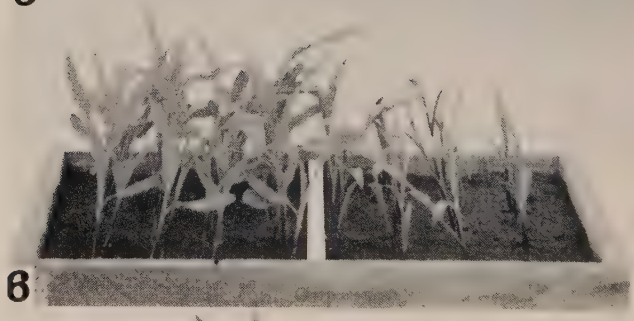

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FIGURE 5. *Left*—a resistant R4 seedling; *right*—a susceptible WF9 seedling. Observe the difference in rootrot damage and in size of the plants. FIGURE 6. *Left*—R4; *right*—WF9. *P. arrhenomanes* inoculum was applied at the rate of 150 cc. per cu. ft. FIGURE 7. A flat similar to the one in Figure 6, except that the inoculum was applied at the rate of 250 cc. per cu. ft. At this rate of application, both inbreds are slightly more retarded.

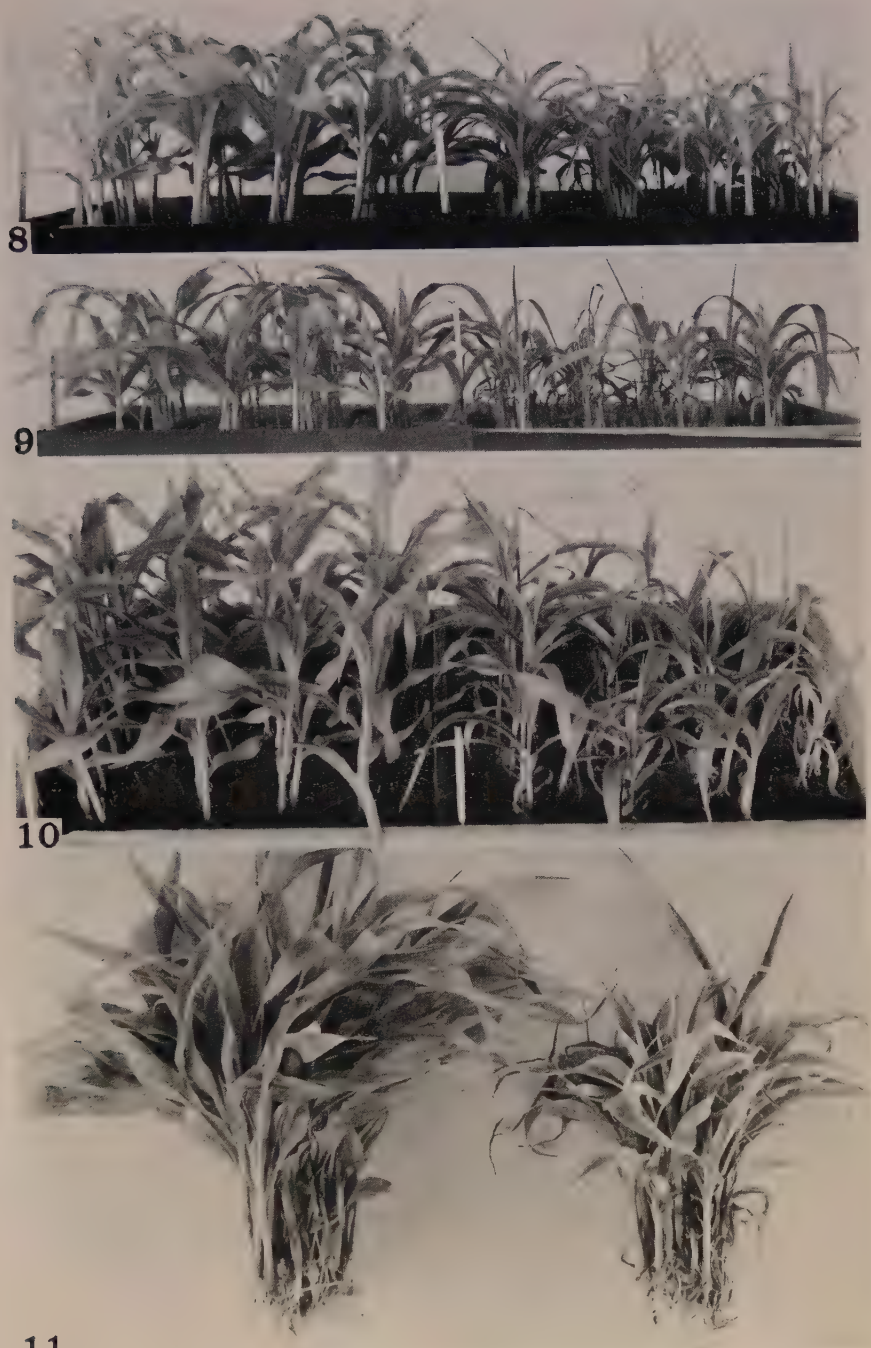

FIGURE 8. Thirty-three-day-old plants. *Left*—R4, a resistant inbred; *right*—WF9, a susceptible inbred, in soil naturally infested with *P. arrhenomanes*. FIGURES 9 and 10 are similar to Figure 8, except that 2 different, naturally infested soils were used. FIGURE 11. Relative size of R4 and WF9 seedlings grown in the naturally infested soil of Figure 9.

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FIGURE 12. Upper row, *left to right* inbreds R4 (resistant) and Hy (susceptible); lower row, *left to right*, double cross R4 × Hy × 187-2 × WF9 and single cross R4 × Hy All grown in soil infested with *P. arrhenomanes*.

TABLE 1.—COMPARATIVE GREEN WEIGHTS OF 4 CORN INBREDS GROWN IN STEAMED SOIL AND IN 3 SOILS NATURALLY INFESTED WITH *P. arrhenomanes*

Inbred	Soil type			
	Arner's loam	Winter's clay loam	King's clay loam	Sterile compost
	Weight in grams[1]			
R4	68[2]	49	60	98
WF9	39	30	54	107
187-2	29	27	42	85
Hy	40	34	49	99

[1] Thirty-one days after planting.
[2] Each figure represents the average weight of 40 seedlings involving 2 replicates.

use of a moderate amount of inoculum (150 to 250 cc. per cu. ft. of soil) and a temperature range of 18° C. to 20° C. proved to be most effective in testing the relative resistance of inbreds.

Comparisons of root systems of seedlings of the different inbreds tested showed that, after several weeks of growth in infested soil in the case of the inbred R4, the root system was extensive with relatively few lesions on its roots. On the other hand, root systems of other inbreds at the same time and under similar conditions, were considerably less extensive and in various stages of rotting (Figure 5).

Since considerable differences in relative resistance of inbreds to *P. arrhenomanes* in artificially inoculated soil were found, it was decided to test some inbreds (R4, WF9, 187-2, and Hy) in soil naturally infested with *P. arrhenomanes*. Winter's clay loam, Arner's loam and King's clay loam were used.

Table 1 shows that R4 produced more top growth than the susceptible inbreds in naturally infested rootrot soil, but this occurred also in the sterile compost. All plants, regardless of the inbred, were larger in the compost soil than in any of the other soils. This was due, for the most part, to the absence of rootrot organisms in the compost but also, perhaps, to the higher fertility level in that soil. Although in the compost soil R4 was not the tallest and sturdiest inbred, nevertheless, in all 3 *Pythium*-infested soils this inbred was consistently taller and sturdier than any of the others, thus indicating that it possessed a high measure of resistance to *P. arrhenomanes* (Figures 8, 9, 10 and 11). It might be mentioned that some of the seedlings of all inbreds tested in infested soils, other than those of R4, consistently showed symptoms of moderate or severe rootrot approximately 28 days after sowing.

The Resistance of Corn and Wheat to P. arrhenomanes and Gibberella zeae

In previous work (5), the writer found that the virulence of *P. arrhenomanes* and *Gibberella zeae* on corn was most severe at relatively low temperatures (15° C.). On the other hand, the same organisms on wheat proved to be most virulent at relatively high temperatures (25° C.). For this reason it appeared possible that the same factor(s) was controlling resistance in each host. To prove or disprove this possibility the relative resistance

of the different corn inbreds to *G. zeae* was carefully tested. Since the inbred R4, which was resistant to *P. arrhenomanes*, proved to be completely susceptible to *G. zeae* and, on the other hand, the inbred LC19, which was susceptible to *P. arrhenomanes*, proved to be partially resistant to *G. zeae*, it was concluded that the resistance of corn to the two pathogens in question could not be controlled by the same factor(s).

Inheritance of Resistance of Inbreds to P. arrhenomanes

In order to obtain more information regarding the inheritance of *Pythium* resistance, the resistant inbred R4 was crossed with the susceptible inbred Hy and this single cross was combined with another single cross produced from the 2 susceptible inbreds 187-2 and WF9. The inbreds R4 and Hy and the single cross produced from them, along with the double cross of the 4 inbreds mentioned above, were grown in soil inoculated with *P. arrhenomanes*. The average weight of 20 plants of R4, Hy, R4 × Hy, and the double cross were 21.5, 12, 24.3, and 38 grams, respectively.

The plants in the single cross developed uniformly and were slightly larger than those of the resistant inbred. The double cross, however, which had 3 susceptible and one resistant grandparent was twice as large as R4 (Figure 12). Hybrid vigour obviously was extremely important. The double-crossed plants were apparently able to grow better in the *Pythium*-inoculated soil because they had the ability to produce many more roots than their ancestral inbreds.

DISCUSSION

It was somewhat surprising to find differences in resistance of the inbred parents to *P. arrhenomanes*, a pathogen which possesses such unspecialized host-parasite relations. Since open-pollinated corn is being replaced so completely by hybrid corn, it is extremely important that none of the disease resistant genes of the former be lost and that the most resistant inbreds available should be used by plant breeders.

However, since 4 inbreds are commonly used to develop each commercial hybrid, considerable breeding manipulation is required to produce a resistant hybrid. At least one of the single crosses must be homozygous resistant if the gene (or genes) for resistance is dominant and all inbreds must be resistant if the genes carrying resistance are recessive. It has proved exceedingly difficult to determine the genetical inheritance of resistance because of the hybrid vigour which results when two inbreds are crossed. Hybrid vigour enables the plant to produce many new roots and thus overcome rootrot to a certain extent.

SUMMARY

Pythium arrhenomanes is widely distributed in southern Ontario and causes a rootrot of field corn which is responsible for depressing the yield and quality of the grain.

Twenty-eight inbred lines of dent corn were tested for susceptibility to *P. arrhenomanes*. Thiram-treated seed was sown in steamed compost soil inoculated with a cornmeal-sand culture of the fungus in formalin-treated flats. These were maintained at relatively low temperatures (20° C.) and illuminated with daylight fluorescent lamps.

Comparisons of green plant weights and root examinations showed that most of the inbreds were completely susceptible to *P. arrhenomanes*, though one (R4) was resistant and some others were intermediate in reaction. Similar results were obtained with 3 different soils naturally infested with *P. arrhenomanes*.

Tests showed that the factor(s) in wheat and corn governing resistance to *P. arrhenomanes* and *Gibberella zeae* are different.

Pythium rootrot may be overcome in two ways, namely, by the capacity of a plant to produce many roots, as exemplified by hybrids, and by physiological resistance, as exemplified by R4, the resistant inbred.

ACKNOWLEDGMENT

The author wishes to express his indebtedness to G. C. Mortimore, of the Harrow Experiment Station, for supplying all seed and especially to L. W. Koch for criticism of this article.

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EFFECT OF PLANT SPACINGS, ROW SPACINGS AND NUMBER OF PLANTS PER HILL ON ADVANCE HYBRID SUNFLOWER

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During the past eight years sunflowers have been grown as an oil seed crop in southern Manitoba. In the first years the acreage was concentrated in an area of 20 to 30 townships in the southern portion of the Red River Valley. In the last three seasons, the crop has been successfully grown in scattered fields over an expanded area of approximately 300 townships. Domestic markets can absorb many times the present production. Thus it is felt that, unless insect or disease hazards develop to an unforeseen extent, the crop will become one of major economic importance over a large section of southern Manitoba within the next few years.

Prior to the introduction of the crop some work on cultural practices had been done at Saskatoon (2). Based on this work rates of seeding were recommended to result in a stand of a plant every 6 inches in the row when rows were 36 to 42 inches apart. Many of the growers believed that this rate was too high. It was felt that there might be a valid basis for these objections. The work conducted at Saskatoon was several hundred miles from the area where the sunflower was being grown as a commercial crop. Weather and soil conditions would obviously be different from those encountered in southern Manitoba. In addition the work at Saskatoon had been chiefly with the Mennonite variety and a strain known as S-490, whereas the plantings in Manitoba were almost entirely the more recently introduced Advance hybrid.

Sugar beets, usually planted at a row spacing of approximately 20 inches, are grown in Manitoba. It appeared desirable to determine if the sunflower crop could be grown at row spacings narrower than the conventional 36 or 42 inches, thereby enabling the farmer to use the same planting and cultivating machinery and the same adjustments of this equipment for the two crops. Corn equipment for check row planting is also available. Therefore the desirability of planting sunflowers in check rows to enable cultivation both ways and better weed control also merited investigation.

In view of these considerations tests were conducted in the three years 1948 to 1950, investigating the effect of various controlled plant spacings and unthinned seeding rates in two row spacings, different number of plants per hill in two check row spacings, and five row spacings with a single plant spacing. This paper will report the effect of these factors on flowering date, plant size, seed yield and seed quality as secured from these tests.

MATERIALS AND METHODS

All tests were conducted in the vicinity of Altona in south central Manitoba on soil classified as Altona Heavy Loam. It is described by the Manitoba Department of Agriculture as "Black earth soil on medium to heavy textured lacustrine deposits". The three seasons in which the tests were conducted had greatly different weather conditions. In 1948 planting was done in the third week of May. Moisture conditions were

[1] Agronomists.

adequate for germination. After emergence a period of three weeks of hot weather followed, then about seven weeks of excellent moisture and growing conditions which allowed the crop to develop very well. This was followed by a warm, dry August and September with no frost so that seed developed and matured fully. The year 1949 had a cool spring and delayed germination followed by a summer and early fall of inadequate moisture and excessive heat resulting in rather poor growing conditions and low yields but a fairly good sample of seed. In 1950 excessive moisture conditions and cool spring delayed planting until early June. An exceptionally cool summer followed resulting in slow development of the crop. A warm, dry September allowed the material to reach partial-to-complete maturity but yields of seed were low and quality poor.

All tests were planted with Advance medium size seed on land following a cereal crop. The land was fall ploughed. Spring tillage consisted of cultivation or disking followed by harrowing to give a fairly firm seed bed and fine tilth. Planting was done with a small garden seeder at a depth of approximately one and one-half inches. Immediately following planting the seeder was weighted and passed over the rows again to pack the soil around the seed. Except for those plots where a specific number of pounds per acre were to be applied, a heavy rate of seeding was used and the stands thinned to the desired plant spacing shortly after emergence. Cultivation during the growing season consisted of inter-row tillage with a garden cultivator and hand hoeing to control the weeds within the row.

Date of flowering was considered as that date at which 80 to 90 per cent of the plants were in bloom. Measurements of plant characters were made at maturity on 5 randomly chosen plants in each plot. Plant height was considered as the full length of the plant with the stem held straight. Head height was the measurement of the head above the soil level.

In 1948 the plots were threshed with a small hand thresher similar to that described by Sheibe (3). In 1949 and 1950 a small power driven rub-bar cylinder type thresher constructed for the purpose was used. After threshing, the material was passed over an office "Clipper" once and the seed weighed to the nearest one-half ounce.

Bushel weight and oil content determinations were made on a single sample from each plot. For oil content a sample of 75 grams was ground in a small corn mill. Two grams of the ground material were then extracted for three hours with 35 cc. of petroleum ether using a metallic spiral reflux condenser mounted in a 250 cc. Erlenmeyer flask. The two-gram sample was wrapped in filter paper and the wrapped sample placed in a single weight paper thimble hung below the condensor. Duplicate samples with this method of extraction usually check within one-half of one per cent. All determinations were expressed on a dry weight basis of whole seed.

Variance analyses and calculations of the lowest significant differences for split plot tests have been made following the methods of Cochrane and Cox (1). In the computations it was found that the lowest significant differences for the comparison of the means of two levels of subplots at different levels of the main plots were in most instances similar or slightly higher than those for comparisons of two levels of subplots at the same main plot level. For simplicity in presentation only the former are given in the tables which follow and they have been used for all comparisons.

Rate of Seeding Test

The test was conducted in a split plot design. The main plots consisted of two row spacings, 18 inches and 36 inches apart. The sub-plots consisted of plants thinned to definite spacings of 6, 12, and 18 inches in the row and three unthinned seeding rates. The latter consisted of 5, $7\frac{1}{2}$ and 10 pounds per acre in the 36-inch rows and comparable rates of 10, 15 and 20 pounds in the 18-inch rows. The five-pound rate corresponds approximately to a 6-inch plant spacing in the 36-inch row. Six replicates were used. In the 36-inch rows the plots consisted of two rows 20 feet long, both rows being harvested. In the 18-inch rows the plots were made up of four rows with only the centre two rows being harvested. Where the 18- and 36-inch row plots adjoined, a 3-foot space was allowed. The harvested row length was one rod.

Plants per Hill Test

This test was similar in design to the rate of seeding test. Main plots consisted of two check row spacings, 36 and 18 inches. Sub-plots consisted of the six levels of plants per hill as follows: 1, 2, 3, 5, 7 and 9. As with the rate of seeding test, 36-inch check row plots consisted of two rows and the 18-inch plots, four rows. Row length was 21 feet with the end hill of each plot being discarded at harvest time. Six replicates were also used in this test.

Row Spacing Test

This was a simple randomized test of four replicates employing the row spacings 18, 24, 30, 36 and 42 inches with plants spaced in the row 6 inches apart for all row spacings. Plot size consisted of three rows 63 feet long with 60 feet of the centre row being harvested. A 3-foot alley was allowed between adjoining plots.

EXPERIMENTAL RESULTS

Rate of Seeding Test

The data from this test for seed yield per acre for the three years together with the means are presented in Table 1. Considering first the mean yields it is seen that the 18-inch plant spacing in the 18-inch rows has given by far the highest yield of 1071 pounds per acre. Except for the next highest yield of 993 pounds per acre from the 12-inch plant spacing in the 18-inch rows, it differs from all other means by an amount greater than that required for significance at the 5 per cent point and in most instances at the 1 per cent point. The high yielding 12-inch plant spacing in the 18-inch rows also differs from all other lower means except that for the 10-pound rate in the 18-inch rows and the 6-inch plant spacing in the 36-inch rows by significant amounts and in several instances at the 1 per cent level. The contrasting low yield of 634 pounds from the 20-pound rate in the 18-inch rows differs from all other mean yields at the 1 per cent level except those from the 18-and 12-inch plant spacing in the 36-inch rows, in which cases the differences are significant at the 5 per cent level.

Considering the 36-inch rows alone, it is seen that the highest yield of 903 pounds per acre has been obtained from the 6-inch plant spacing. It differs from the two lower yielding and wider plant spacings of 12 and

TABLE 1.—EFFECT OF TWO ROW SPACINGS, THREE PLANT SPACINGS IN THE ROW AND THREE UNTHINNED SEEDING RATES ON THE SEED YIELD OF ADVANCE SUNFLOWER IN POUNDS PER ACRE

Row Spacing	Plant Spacing or Seeding Rate	1948	1949	1950	Mean
18 in.	18 in.	1322	810	1081	1071
18 in.	12 in.	1288	730	961	993
18 in.	6 in.	1065	625	841	844
18 in.	10 lb.	1225	704	846	925
18 in.	15 lb.	1032	639	730	800
18 in.	20 lb.	758	562	582	634
36 in.	18 in.	1097	548	628	758
36 in.	12 in.	1056	604	676	779
36 in.	6 in.	1185	707	816	903
36 in.	5 lb.	1158	620	716	831
36 in.	7½ lb.	1096	622	770	829
36 in.	10 lb.	1052	597	802	817
	Lowest Significant Difference 5%				120
	Lowest Significant Difference 1%				160

18 inches at the 5 per cent level of significance. No other significant differences exist in the comparisons of the mean yields obtained from this row spacing.

An interesting feature of the yield data is the same yielding order, especially in the 18-inch rows for the various plant spacings and seeding rates. The yielding order in this row spacing is identical for the years 1948 and 1950 and only the positions of the 6-inch plant spacing and 15-pound rate are interchanged for the 1949 results. The yielding order is not so consistent in the 36-inch rows but it is notable that the highest yield in each of the three years has been obtained from the 6-inch plant spacing. It is also of interest that in the 36-inch row spacing the wide plant spacing of 18 inches has been the lowest yielding in the two years 1949 and 1950. Furthermore the 12-inch spacing in the wider row spacing has been the second lowest yielding in the two years 1948 and 1950.

Another feature worthy of comment is the yield obtained from the 10-pound seeding rate in the 18-inch rows and the comparable 5-pound rate in the 36-inch rows. This seeding rate is designed to give a plant approximately every 6 inches in the row. The stand counts show that the average plant spacing obtained was 6.5 inches. It is seen that in the 18-inch rows this rate yields higher than the 6-inch plant spacing or that it tends to approach the yield obtained from the wider plant spacings of 12 and 18 inches. In the 36-inch row spacing this rate yields lower than the 6-inch thinned plant spacing or again tends to approach the yield obtained from the wider plant spacing of 12 and 18 inches. It is suggested that this feature is a manifestation of the random plant spacing obtained in an unthinned seeding rate. It is obvious that there would be some plants in the 5-pound seeding rate, 12 to 18 inches from the adjoining plant or, in other words, using this seeding rate, one approaches to some extent the condition existing for the wider plant spacings and obtains yields which correspond to them.

TABLE 2.—EFFECT OF TWO ROW SPACINGS, THREE PLANT SPACINGS IN THE ROW AND THREE UNTHINNED SEEDING RATES ON PLANT AND SEED CHARACTERS OF ADVANCE SUNFLOWERS. 1948–50.

LINEAR MEASUREMENTS IN INCHES, WEIGHT IN POUNDS

Row Spacing	Plant Spacing or Seeding Rate	Days to flower	Height	Head Diam.	Head Height	Weight per Bushel	% Oil in Seed
18 in.	18 in.	84.0	47.6	5.5	36.8	27.66	35.40
18 in.	12 in.	85.0	48.5	4.7	39.2	28.02	35.44
18 in.	6 in.	85.7	50.2	4.2	43.3	28.56	34.44
18 in.	10 lb.	85.2	51.3	4.7	43.6	28.37	35.00
18 in.	15 lb.	85.2	52.4	4.1	43.8	29.07	34.56
18 in.	20 lb.	86.0	51.9	3.4	46.7	29.27	34.53
36 in.	18 in.	85.0	48.3	6.6	35.9	26.72	34.57
36 in.	12 in.	84.8	48.6	6.0	36.9	27.63	34.06
36 in.	6 in.	84.8	52.1	5.4	41.3	28.48	35.49
36 in.	5 lb.	85.2	51.1	5.4	40.7	27.60	35.03
36 in.	7½ lb.	85.4	51.9	4.7	42.9	28.27	35.03
36 in.	10 lb.	85.0	51.6	4.5	43.1	28.80	35.11
	L.S.D. 5%	.86	—	—	—	.72	.72
	L.S.D. 1%	1.13	—	—	—	.95	.96

The data from the other factors studied in the rate of seeding test are presented in Table 2. For brevity, only the 3-year means are presented. In the number of days from seeding to flowering the 18-inch row spacing shows a progressive increase as the plant spacing is reduced or the seeding rate increased. The difference between the 18-inch plant spacing and the 20-pound seeding rate is significant at the 1 per cent level. In the 36-inch rows the number of days from seeding to flowering for all plant spacings and seeding rates is virtually the same.

In plant characters the height or length of stem tends to increase in both row spacings as the plant spacing is reduced or the seeding rate increased. As would be expected the head diameter is reduced in both row spacings as the plant spacing in the row decreases.

In head height there is a progressive increase in the 36-inch row spacing as the plant spacing is reduced, while in the 18-inch row spacing a fairly uniform level is obtained at the 6-inch plant spacing or 10-pound seeding rate with the exception of the greater height shown by the 20-pound rate. However, the latter may be an expression of experimental error. This increased head height with reduced plant spacing is desirable for combine harvesting.

In bushel weight for both row spacings there is an increase as the plant spacing in the row is reduced. In both row spacings the bushel weight shown by the 18-inch plant spacing is the lowest differing from all others at either the 1 or 5 per cent level in the 36-inch rows and all others except the 12-inch spacing in the 18-inch rows. It is notable that in the 36-inch rows the bushel weight of the 5-pound seeding rate tends to approach that from the wider plant spacings of 12 and 18 inches. This is probably an expression

of the random plant spacing discussed above with respect to yield per acre. To a lesser extent the same also holds true for the 10-pound or comparable seeding rate in the 18-inch row spacing.

For percentage oil in the seed there is an indication of a progressive increase as plant spacing decreases in the 36-inch rows. This increase appears to be very closely associated with bushel weight. The low figure of 34.06 per cent obtained from the 12-inch plant spacing differs significantly at the 1 per cent level from all other plant spacings except the 18-inch one.

In the 18-inch rows the data for percentage oil are quite different. There appears to be a progressive decrease in oil content as plant spacing decreases and the oil content appears to be negatively associated with bushel weight. The two highest figures are obtained from the 18- and 12-inch plant spacing. They both exceed the 6-inch spacing, 15-pound and 20-pound seeding rates at the 1 per cent level. It is difficult to offer an explanation for this behaviour. It is probable that the increasing bushel weight with reduced plant spacing is an expression of smaller seed size. There has been a suggestion from previous work that reducing seed size increases percentage kernel and oil content (2). However, it appears that in the 20-pound seeding rate the reduction has gone beyond the optimum level for maintaining maximum oil content in the seed. For some reason the percentage hull has probably been increased and this increase in the non-oil bearing portion of the seed results in a lower oil content for the whole seed. The lower oil content may also be an expression of the later maturity of the heavy seeding rate as shown by a larger number of days from seeding to flowering.

The results from the rate of seeding test suggest that the Advance variety of sunflower is more sensitive to reduction of plant spacing in the narrow 18-inch rows than in the 36-inch rows. For example it has been observed that the highest yielding as well as the lowest yielding plots were obtained in the 18-inch rows at the two extreme plant spacings. Furthermore, there were differences in the number of days from seeding to flowering in the 18-inch rows not shown in the 36-inch rows. In the 36-inch rows there were no great differences in yield except that the wider plant spacings were lower and differed significantly from the 6-inch spacing. There was also no difference in the number of days from seeding to flowering in the 36-inch spacing.

The results suggest that, if one wishes maximum yield of good quality seed from the Advance sunflower, a relatively wide plant spacing of 12 to 18 inches should be employed in 18-inch rows. Besides being high yielding this arrangement has given the seed of highest oil content, and earliest flowering. The arrangement has the disadvantage of relatively large head size and rather low hanging heads which may tend for greater losses at harvesting and more wear and tear on the harvesting machinery. If the grower is planning on use of the 36-inch or conventional spacing of rows, it appears that he is well advised to plan his seeding rate to give a plant spacing of 6 inches apart in the row. This plant spacing has given the highest yield of seed in the wider row spacing and the highest oil content in the test. The bushel weight is also among the highest and plant features are desirable in that the head size is not objectionably large and the head height is considerably greater than that obtained in the wider plant spacings.

TABLE 3.—EFFECT OF CHECK ROW PLANTING AT 18 AND 36-INCH SPACINGS WITH SIX LEVELS OF PLANTS PER HILL ON THE SEED YIELD OF ADVANCE SUNFLOWER IN POUNDS PER ACRE

Check Spacing	Plants per Hill	1948	1949	1950	Mean
18 in.	1	1947	844	1129	1307
18 in.	2	1734	970	996	1233
18 in.	3	1474	895	942	1104
18 in.	5	1074	790	613	826
18 in.	7	1064	668	415	716
18 in.	9	822	638	387	616
36 in.	1	937	460	512	636
36 in.	2	1163	552	666	794
36 in.	3	1167	702	563	811
36 in.	5	1279	759	624	887
36 in.	7	1372	738	719	943
36 in.	9	1423	767	598	929
Lowest Significant Difference 5%					107
Lowest Significant Difference 1%					143

Plants per Hill Test

The yield data from the plants per hill test are given in Table 3. Examination of the mean yields for the three years shows that there is a progressive decrease in yield per acre as the number of plants per hill is increased in the 18-inch check row spacing and a progressive increase in the 36-inch spacing. As was the case for the rate of seeding test, by far the highest yield was obtained from the stand of a single plant spaced 18 inches both ways. This high figure of 1307 pounds per acre differs from all other yields by significance at the 1 per cent level except that from the two plants per hill in the 18-inch spacing. The second highest yield of 1233 pounds secured from two plants per hill in the 18-inch spacing also differs by significance at the 1 per cent level from all other mean yields except that from the one plant per hill in the 18-inch spacing. Another feature of the data which is somewhat comparable to that obtained from the rate of seeding test is the low yield of the nine plants per hill or heavy seeding rate in the 18-inch spacing. The difference between this figure of 616 pounds and all others, except that for the seven plants per hill in the same spacing and the one plant per hill in the 36-inch spacing, is significant at the 1 per cent level.

In the matter of yielding order in the various years it is seen that there is considerable similarity. In the 18-inch spacing the order is identical for the years 1948 and 1950 while the one, two and three plants per hill are interchanged for 1949. The yielding order is not quite so consistent in the 36-inch spacing. That for 1948 and 1949 is identical except for an interchange of the five and seven plants per hill. The order for 1950 is different, but it is notable that the one plant per hill ranked sixth or was the lowest yielding. Also the relatively large number of seven plants per hill ranked highest in yield in 1950.

TABLE 4.—EFFECT OF CHECK ROW PLANTING AT 18 AND 36-INCH SPACINGS WITH SIX LEVELS OF PLANTS PER HILL ON PLANT AND SEED CHARACTERS OF ADVANCE SUNFLOWER. LINEAR MEASUREMENTS IN INCHES, WEIGHT IN POUNDS

Check Spacing	Plants per Hill	Days to Flower	Height	Head Diam.	Head Height	Weight per Bushel
18 in.	1	85.7	50.6	6.2	38.3	26.39
18 in.	2	85.7	54.1	4.9	45.2	27.08
18 in.	3	86.4	54.5	4.5	45.8	27.55
18 in.	5	87.1	54.2	3.7	48.0	27.77
18 in.	7	87.4	52.8	3.2	47.7	28.17
18 in.	9	87.6	53.2	3.1	48.5	28.27
36 in.	1	85.6	48.8	8.0	33.3	25.63
36 in.	2	86.2	52.0	6.9	37.1	26.40
36 in.	3	86.8	52.4	5.9	41.2	27.01
36 in.	5	86.8	52.1	5.3	41.3	27.52
36 in.	7	87.3	52.9	5.0	42.0	27.34
36 in.	9	87.1	53.7	4.6	44.3	27.69
	L.S.D. 5%	0.83	—	—	—	0.81
	L.S.D. 1%	1.10	—	—	—	1.09

The data for the other characters studied in the plants per hill test are presented in Table 4. To a considerable extent these data are comparable to those resulting from the rate of seeding test. There is some difference in the behaviour of the days from seeding to flowering in that significant differences exist in both spacings whereas in the other test they occurred only in the 18-inch rows. In both the 18-inch and 36-inch check row spacing, the number of days required to flower increases as the number of plants per hill increases. In the matter of plant height there is an increase in both spacings with increasing number of plants per hill. This increase is more progressive in the wider spacing than in the narrower spacing. The greatest height is reached in the three and five plants per hill of the 18-inch spacing whereas the greatest height for the 36-inch spacing is not reached until the nine plants per hill level.

There is a progressive decrease of head diameter as the number of plants per hill increases in both spacings. Head height, as would be expected, is closely negatively associated with head diameter. It shows a progressive increase in height in the 36-inch spacing as the number of plants per hill increases. In the 18-inch spacing there is a progressive increase up to five plants per hill after which the differences are of no consequence. Comparison of the two spacings shows that the one plant per hill is 5 inches higher in the 18-inch spacing than in the 36-inch spacing. This is a significant amount for harvesting considerations.

Of seed characters only bushel weight was studied in the plants per hill test. Data on oil content were not obtained because of the time and labour involved. In bushel weight there is a progressive increase in both spacings as the number of plants per hill increases. The low figure of 25.63 pounds for the one plant per hill in the 36-inch spacing differs from all others at the 1 per cent level with the exception of the two plants per hill in the same

TABLE 5.—EFFECT OF FIVE ROW SPACINGS WITH UNIFORM PLANT SPACING IN THE ROWS OF 6 INCHES ON THE SEED YIELD OF ADVANCE SUNFLOWER IN POUNDS PER ACRE

Row Spacing	1948	1949	1950	Mean
18 in.	1206	901	575	894
24 in.	1368	816	630	938
30 in.	1300	746	681	909
36 in.	1284	708	688	893
42 in.	1228	679	741	883

No significant differences.

TABLE 6.—EFFECT OF FIVE ROW SPACINGS WITH UNIFORM PLANT SPACING OF 6 INCHES IN THE ROWS ON PLANT AND SEED CHARACTERS OF ADVANCE SUNFLOWER. LINEAR MEASUREMENTS IN INCHES, WEIGHT IN POUNDS

Row Spacing	Days to Flower	Height	Head Diam.	Head Height	Weight per Bushel
18 in.	84.0	51.2	4.8	45.8	29.09
24 in.	83.8	52.2	5.3	44.2	28.86
30 in.	83.8	52.8	5.5	43.8	28.38
36 in.	83.5	53.5	6.0	45.0	28.14
42 in.	83.3	53.6	6.3	41.9	27.92
L.S.D. 5%	None	—	—	—	.63
L.S.D. 1%	None	—	—	—	.84

spacing. In the 18-inch spacing the one plant per hill figure of 26.39 pounds also differs from the higher figures of all other spacings by significance at the 1 per cent level. The only exception is that for the comparison of the one and two plants per hill in this spacing in which case the difference approaches the 5 per cent level.

Row Spacing Test

Table 5 contains the yield data from the row spacing test for the three years. Variance analyses for these data show that there is no significant difference between the means of the different spacings for the three years. However, unlike the other tests reported in this paper, the yielding order of the different row spacings is not the same for the three seasons. This is particularly notable in the comparison of the 1949 and 1950 data in which the yielding order is exactly reversed. It appears that in 1949 the weather conditions favoured the narrow 18-inch row spacing whereas in 1950 they favoured the 42-inch row spacing.

The other data assembled from the row spacing test are summarized in Table 6. No great differences are evident. In days from seeding to flowering there is a slight but inconsequential decrease as the row spacing increases. There is a slight trend for increasing plant height with increasing row spacing. This is somewhat the reverse of that shown by the other tests where an increased height was obtained by decreasing the plant

spacing or increasing the plant concentration per unit area. Head diameter shows an increase as the row spacing increases. This would be expected. Similarly head height shows a fairly close negative association with head diameter in that there is a decreasing head height as the row spacing increases and as the head diameter increases. In weight per bushel there is a decrease as the row spacing increases. This is in line with the other tests which showed an increasing weight per bushel as the concentration of plants increased. The high figure of 29.09 pounds obtained from the 18-inch spacing differs significantly at the 1 per cent level from the two widest spacings of 36-and 42-inch rows. Other significant differences at both the 5 and 1 per cent levels also exist.

DISCUSSION

The outstanding feature of the results reported here is the high yield of seed obtained from a stand of a single plant spaced 18 inches both ways. This arrangement was highest in both the "rate of seeding test" and in the "plants per hill test". It also has the desirable features of relatively high bushel weight and also high oil content. Its chief undesirable feature is the rather large head size associated with it. Such a large head results in rather low hanging heads, and would contribute to losses in harvesting. However, should a stronger stemmed variety than the present Advance be obtained this objection would be minimized. There is also the added undesirable feature of heavier wear on the combine from the large heads. From the practical standpoint check rows at such a close spacing as 18 inches are undesirable. However, it would seem that the grower may be able to obtain yields approaching those from the 18-inch check row with one plant per hill by using a drilled row of this spacing and adjusting his seeding rate so that he is obtaining a plant every 12 to 18 inches in the row. Certainly the results from the 18-inch rows of the rate of seeding test show that a close plant spacing such as 6 inches or narrower should be avoided in a narrow row spacing.

It is incidental to note also that for a 3-year average the narrow plant spacing of 6 inches in the 18-inch row will not result in any reduced yield in comparison with a similar plant spacing in a 36-inch row.

It appears, then, that narrow row spacings can be recommended to those growers who wish to employ such row spacings in other crops, in particular sugar beets. This would permit the growers to use the same tillage and planting equipment for both crops thereby reducing the investment in machinery and also minimizing the amount of labour required for adjusting the equipment in moving from one crop to another.

A number of features concerning the 36-inch row are worthy of comment. In the first place the rate of seeding test shows that the highest yield is obtained from a spacing of 6 inches between plants in the row. While it does not appear possible to obtain such a uniform spacing with a random or unthinned seeding rate, there is evidence that, if the seeding rate is not planned to result in a spacing which is on the average about 6 inches, the yields will be reduced. Both the 12- and 18-inch plant spacing in the 36-inch rows were lower than that for the 6-inch spacing, the difference being significant at the 5 per cent level in both instances. In addition the

wider spacings have larger heads which are lower and more difficult to handle with harvesting machinery. It is also felt that such large heads would dry out more slowly at maturity. This feature however has not been verified.

Providing the yield is satisfactory, check rowing at 36 or 42 inches would be desirable from the weed control standpoint. The two tests "rate of seeding" and "plants per hill", both contained plots of a single plant in check rows at 18-inch spacing. By expressing the yields of the 36-inch row spacing in both tests in terms of percentage of the 18-inch single plant in check row plots, they can be brought to a comparable basis. The means obtained from such a transformation are shown in Table 7.

TABLE 7.—YIELD OF SEED FROM 36-INCH DRILLED ROWS AND 36-INCH CHECK ROWS AT VARYING SEEDING RATES EXPRESSED AS PERCENTAGE OF THE YIELD FROM A SINGLE PLANT STAND IN 18-INCH CHECK ROWS

Drilled Rows		Check Rows	
Seeding Rate or Plant Spacing	Yield	Plants per Hill	Yield
18 in.	72.2	1	50.0
12 in.	76.2	2	64.0
6 in.	87.7	3	67.4
5 lb.	79.6	5	72.9
7½ lb.	79.6	7	77.8
10 lb.	79.8	9	75.0
L.S.D. for comparing drilled with check row 5% level			9.4%
L.S.D. for comparing drilled with check row 1% level			12.6%

The data of Table 7 suggest that if a high number of plants per hill is used in 36-inch check rows, yields will be very similar to those from drilled rows of the same spacing. The figures of 77.8 per cent and 75.0 per cent obtained for the seven and nine plants per hill are lower than most of those from the drilled rows but the differences reach significant levels only for the comparisons with the 6-inch plant spacing. The differences for the comparisons with the unthinned seeding rates are not significant and do not even approach significant levels. Such observations warrant further investigation of the yielding ability of check rows on a field scale. It is quite probable that such a planting method would be especially desirable on weedy fields where cross cultivation of check rows would make weed control easier. The plates of present corn planters which are commonly used for sowing the sunflower crop may not be suitable for depositing as much as seven to nine seeds per hill. However, it would be a small matter to have special plates made to permit this. The seed trade have also adopted the policy of sizing sunflower seed. It is possible that as many as seven to nine seeds per hill could be dropped of the small size which is now being offered.

SUMMARY

1. The yield, plant characters, bushel weight and per cent oil of the seed of Advance sunflower were determined for three seasons in a "Rate of Seeding Test", consisting of 18- and 36-inch rows with plant spacing in the row of 6, 12 and 18 inches, and unthinned seeding rates of 5, 7½ and 10 pounds per acre based on 36-inch rows.

2. Data on the same characters except for oil content were obtained in a "Plants per Hill Test", comprised of 18- and 36-inch check rows with one, two, three, five, seven and nine plants per hill and in drilled rows 18, 24, 30, 36 and 42 inches apart, with a plant spacing of 6 inches in the rows.

3. No significant differences occurred in seed yield in the rows of different spacing when the plants were spaced six inches apart. Plant height and head diameter increased and head height decreased as row spacing increased in this test.

4. In both the "Rate of Seeding Test" and the "Plants per Hill Test" the highest seed yield was obtained from the stand of a single plant spaced 18 inches in the two directions.

5. As plant spacing was reduced or the number of plants per hill increased in the 18-inch rows, the yield of seed was reduced.

6. In the 36-inch rows the yield of seed increased as plant spacing was reduced from 18 to 6 inches, or the number of plants per hill increased from one to seven.

7. Days from seeding to flowering increased as plant spacing decreased or number of plants per hill increased in both 18- and 36-inch row spacings. The same was true for plant height, head height and weight per bushel of seed with the reverse holding for head diameter.

8. Percentage of oil in the seed, determined in the "Rate of Seeding Test" only, showed a progressive increase as plant spacing decreased in the 36-inch rows with the reverse occurring in the 18-inch rows.

9. The results suggest that the Advance variety of sunflowers can be grown successfully in row spacings as narrow as 18 inches providing plant spacing in the row is kept at 12 to 18 inches. In 36-inch rows a plant spacing of 6 inches in the row appears optimum with evidence that satisfactory yields can also be obtained from check rows at this spacing, if the number of plants per hill is maintained at seven to nine.

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REMOVAL OF AIR FROM DAIRY STABLES

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Two different systems of dairy stable ventilation are being used on the majority of farms in Canada, as developed by J. G. Rutherford, of the Canada Department of Agriculture, and F. H. King, of the University of Wisconsin. In the Rutherford system of ventilation, air is removed from a stable at the ceiling, while with the King system air is removed from the building at floor level. Differences of opinion have arisen regarding the merits of removing air from stables at these two locations.

To secure data on these systems of ventilation, experiments have been conducted in the Central Experimental Farm stables and in those on private farms. Records were obtained on air movement, temperature and humidity conditions in the stables.

In the ventilation of a dairy stable the primary purpose of the ventilating system is to remove the moisture released by the live stock from the building. If sufficient air is moved through a stable to carry out this moisture, there are normally no problems of odour or excessive amounts of carbon dioxide in the air. However, to remove this moisture from a stable the limiting factor is the heat which is available for warming the cool fresh air for ventilation purposes. The heat produced per animal unit is fairly constant, but is limited to approximately 3,000 B.t.u.'s per hour for a dairy cow. Moreover, all of this heat is not available for warming air for ventilation purposes. Thus, from the standpoint of heat conservation, the location of an outlet ventilator in a stable requires consideration.

Another factor in the location of a ventilator outlet at the floor or ceiling of a stable is that of convenience in providing for this outlet within the barn structure. Since an outlet flue or stack should be located in a warm part of the stable, it is usually difficult to secure a suitable location for any ventilator which draws air from the floor of the building. Almost any location in pens or alleyways of the stable interferes with the use of feed-carts or cleaning operations in the building. In some stables the installation of a ventilator which starts at the floor reduces the barn capacity by one cow stall. If electric fans are placed in a wall near the floor they are subject to damage by animals, carriers and carts. Moreover, with this location for a fan unit, snow on the outside of the wall may cover the air outlet. If the fan is placed near the ceiling, in conjunction with a duct leading to the floor, this duct presents the same problems of location as ventilator flue or stack.

In periods of relatively mild weather during winter the volume of air required for ventilation may be as much as 150 cubic feet per minute per animal, but under this condition heat conservation is no problem. In fact, a cooling effect would be desirable and thus the ventilator unit might be located where it would remove the warmest air. In cold weather, when the temperature is minus 15° F. or less, air requirements for the removal of

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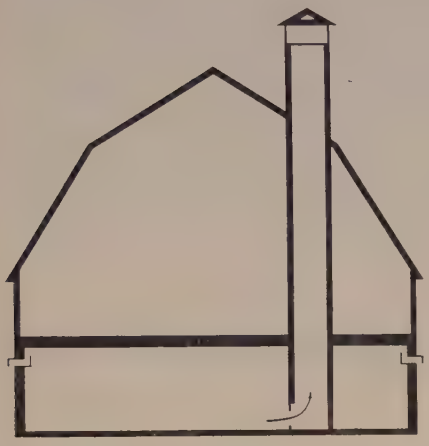
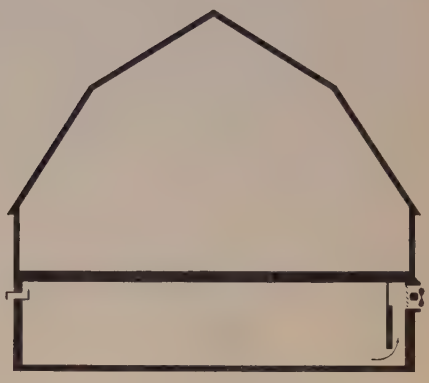
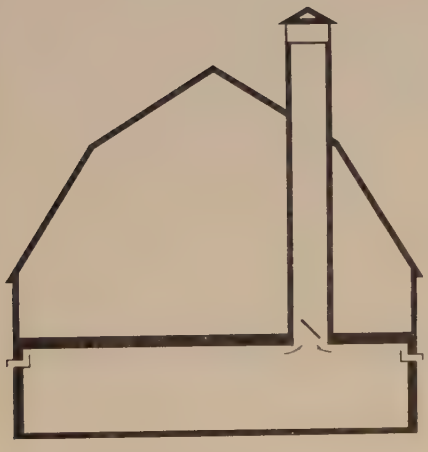


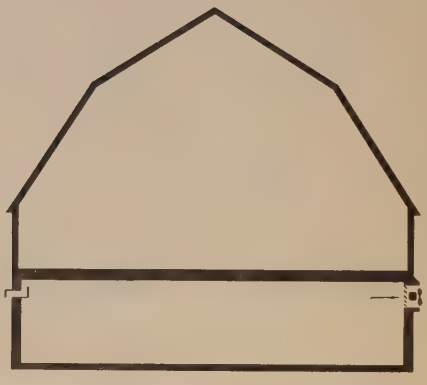
Flue ventilator — floor outlet



Fan ventilator — floor outlet



Flue ventilator — ceiling outlet



Fan ventilator — ceiling outlet

moisture may be less than 35 cubic feet per minute per animal unit. It is under these conditions that the maximum number of grains of moisture should be removed from the stable with the minimum loss of heat per cubic foot of air removed from the building.

To conserve heat there is a tendency to believe that a ventilator should remove the cooler air which is located near the floor. However, the removal of cool air may not represent the greatest economy of heat when the moisture-carrying capacity of air is taken into consideration. If warmer air at the ceiling will carry out a proportionally greater quantity of water than drier and cooler air at the floor, then the removal of warm air from the ceiling provides better conservation of heat.

TABLE 1.—HEAT LOSSES FROM FLOOR AND CEILING VENTILATORS

B.t u.† loss per 100 grains of moisture removed at floor and ceiling outlets

Outside temperature Degrees F.	Inside conditions		Heat loss per 100 grains removed from barn*	Reduction in heat loss by air removal at ceiling in B.t.u.'s**
	Degrees F.	R.H. per cent		
− 9	Floor 47.5	76	46.6	
	Ceiling 51.9	73	44.8	1.8
−11	Floor 49.0	73	45.3	
	Ceiling 54.0	76	43.7	1.6
−15	Floor 50.0	81	43.6	
	Ceiling 52.0	78	43.0	0.6
	Floor 48.0	75	46.2	
	Ceiling 51.5	80	42.7	3.5
	Floor 48.5	83	42.8	
	Ceiling 52.5	75	43.8	−1.0
−30	Floor 45.0	81	45.3	
	Ceiling 50.5	84	41.9	3.4
	Floor 45.0	81	45.3	
	Ceiling 49.5	74	43.2	2.1
	Floor 43.5	92	42.4	
	Ceiling 48.0	87	42.1	0.3
	Floor 47.0	90	43.8	
	Ceiling 51.5	78	43.3	0.5
	Floor 48.5	84	42.8	
	Ceiling 51.5	84	38.3	4.5
	Floor 44.0	96	41.0	
	Ceiling 48.0	90	41.2	−0.2

* Expressed in B.t.u.'s per 100 grains of moisture.

** Expressed as B.t.u.'s of heat which is contained in the air removed from a stable, per 100 grains of moisture.

† British Thermal Unit is approximately the amount of heat required to raise 1 lb. of water 1 degree Fahrenheit to 65° F.

Data presented in Table 1 show temperature and humidity conditions at which air was exhausted from the stable when the outside temperature ranged from 9 to 30 degrees below zero. Column 4 of this table shows the loss of heat per 100 grains of moisture removed from a stable. It may be noted that the heat loss is usually greater when air is removed at the floor than when it is removed from near the ceiling. Therefore, to conserve heat, it is normally more advantageous to remove air from the ceiling level of a stable. By this small saving of heat in removing air from near the ceiling it is somewhat easier to maintain a desirable temperature in the building. This location of outlet ducts or fans also eliminates other problems of installing ventilators in dairy stables.

SUMMARY

Data secured on removal of air in low temperature periods by outlets located at the ceiling and floor indicate that it is more feasible to exhaust air from the ceiling level. The loss of heat per grain of moisture exhausted is normally less if the air is removed by a ceiling outlet. Convenience of location and reduced costs of the ceiling outlet are also important considerations when placing a foul air outlet in a stable.

SMUTS OF COARSE GRAINS IN MANITOBA[1]

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During the past 50 years, great improvements have been made in methods and equipment used in the cleaning and treating of seed grain. Notable progress has also been made in developing more effective seed-treating chemicals, particularly those used for the control of the cereal smuts. Chemicals containing organic mercury as the active ingredient have proved to be especially effective for smut control and their superiority over the older seed-treating substances, such as copper sulphate, copper carbonate, and formaldehyde, has been well established. In addition to being very effective, the newer chemicals can be applied as dusts, liquids, or slurries. As a result of these advances, it should now be possible for the farmer to produce crops of wheat, oats, and barley that are practically free from the common seedling-infecting smuts.

The fact, commonly observed, that losses from the cereal smuts are still relatively high (2, 3) particularly in the coarse grains—oats and barley—suggests either that many farmers are not familiar with the newer seed disinfectants and the methods of applying them, or that for some reason these methods are not readily adaptable to farm practice. It was with a view to obtaining information about seed-treatment practices used in Manitoba, and their effectiveness in controlling smut, that a seed-drill survey of oats and barley was undertaken by the Dominion Laboratory of Plant Pathology, Winnipeg, in co-operation with the Provincial Extension Service. This survey was made during the three years, 1947 to 1949, inclusive. It involved the collection and examination of a total of 892 seed samples and the inspection of the fields seeded with the lots of grain from which samples had been taken.

SURVEY METHODS

Seed samples of oats and barley were obtained from farmers' seed-drills in each district of Manitoba by the District Representatives of the Provincial Extension Service. As far as possible the samples were taken at random. After being labelled as to variety, date and kind of seed treatment, if any, and date of seeding, the samples were sent to the laboratory where they were examined for smut spore-load by the method described by Cherewick (1).

The fields sown with the sampled seed were inspected shortly after the plants had come into head, and the percentage of smutted heads in each field was determined by counting 100 heads in each of five to ten spots chosen at random through the field. Representative samples of the loose smuts of barley were collected and brought to the laboratory where, by means of spore germination tests, the loose and the false loose smuts were differentiated. The total counts for smut of barley were then corrected

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by deducting from them the proportion of heads found to be infected with true loose smut. The corrected counts were taken to represent the number of heads infected with covered and false loose smuts, both of which are controllable by the ordinary seed treatments.

RESULTS

Examinations of 892 seed-drill samples, the results of which are summarized in Table 1, revealed that, with the possible exception of one oat sample, none was entirely free from smut spores. Approximately 38 per cent of the samples carried a trace of spores while the rest carried light to heavy spore-loads. Of particular significance is the fact that, although samples of Registered and Certified seed carried lighter spore-loads than those of ordinary commercial seed (Table 2), none was smut-free. In general, oat samples carried considerably lighter spore-loads than barley samples and a higher proportion had only a trace of spores.

TABLE 1.—SMUT SPORE-LOADS ON FARMERS' SEED GRAIN IN MANITOBA DURING THE PERIOD 1947 TO 1949, INCLUSIVE

Year	Spore-load[1]	Oats		Barley		Mean
		No. of samples	Percentage	No. of samples	Percentage	Percentage
1947	Tr.	45	50.5	28	24.6	36.0
	L–H	44	49.5	86	75.4	64.0
1948	Tr.	101	67.3	63	40.1	53.4
	L–H	49	32.7	94	59.9	46.6
1949	Tr.	59	32.8	45	22.3	27.1
	L–H	121	67.2	157	77.7	72.9
Mean	Tr.	205	48.9	136	28.6	38.1
	L–H	214	51.1	337	71.4	71.9

[1] Tr. = Trace, less than one part of smut spores to 1,000,000 parts of seed by weight.
L–H = Light to heavy spore-loads (1 : 1,000,000 and heavier).

TABLE 2.—DISTRIBUTION OF SMUT SPORE-LOADS IN REGISTERED, CERTIFIED, AND COMMERCIAL SEED GRAIN IN MANITOBA

Grain samples		Registered		Certified		Commercial	
		Spore-load					
		Tr.	L–H	Tr.	L–H	Tr.	L–H
Oats	No. of Samples	12	5	7	3	186	206
	% of total	70.6	29.4	70.0	30.0	47.2	52.6
Barley	No. of samples	10	11	17	7	110	318
	% of total	47.6	52.4	70.8	29.2	25.7	74.3
Mean	No. of samples	22	16	24	10	296	524
	% of total	57.9	42.1	70.6	29.4	36.1	63.9

TABLE 3.—THE EFFECT OF SPORE-LOAD AND SEED TREATMENT ON THE PERCENTAGE OF SMUT IN COARSE GRAIN

Seed grain and spore-load		Percentage of smut in the field, exclusive of the loose smut of barley, after different seed treatments												
		Untreated		Ceresan		Leytosan		Formaldehyde		Panogen		Bluestone		Mean
		No. of fields	% smut	No. of fields	% smut	No. of fields	% smut	No. of fields	% smut	No. of fields	% smut	No. of fields	% smut	% smut
Oats	Tr.	127	0.46	30	0.11	17	0.13	27	0.16	1	0	1	0	0.34
	L–H	129	2.14	26	0.42	24	0.76	17	1.61	1	0	1	Tr.	1.68
Barley	Tr.	43	1.92	46	0.26	28	0.40	14	1.49	1	0	—	—	0.96
	L–H	158	3.88	64	0.87	52	2.45	45	3.68	7	Tr.	3	3.50	2.95
Mean		—	2.25	—	0.49	—	1.36	—	2.20	—	Tr.	—	2.10	1.76

When the data on seed treatments were tabulated and studied it became obvious that, in spite of numerous publications emphasizing the necessity of proper treatment for smut control (5), only 47 per cent of the samples of oats and barley represented seed lots that had been treated. Even more significant is the fact that some farmers still use copper sulphate (bluestone), and a relatively high percentage use formaldehyde for seed treatment. It has been amply demonstrated (3, 4, 5) that these two seed disinfectants are less efficient in controlling smut in coarse grains than are some of the organic mercury compounds. The results of this survey, summarized in Table 3, show even more emphatically the greater effectiveness of the organic mercury compounds in comparison with the earlier seed disinfectants.

The relatively low percentage of seed receiving any treatment, and the use of older and less effective seed disinfectants, are conditions applicable not exclusively to Manitoba farmers. Based on the total amount of seed disinfectants sold in Canada and the number of acres planted to cereals and flax during the years 1947 to 1949 inclusive, as given by the Dominion Bureau of Statistics, an average of only 44.6 per cent of seed had been treated. This estimate is based on the assumption that all of the seed disinfectants sold during the period had been used for seed treatment. The estimated average percentage of seed treated for the whole of Canada is even lower than that found in Manitoba. Moreover, the proportion of the older seed disinfectants, formaldehyde and copper compounds, to the organic mercury compounds sold in Canada is very high.

The effects of smut spore-load and different seed treatments on the amount of smut developing in the field are shown in Table 3. The data presented in this table reveal that seed bearing only a trace of spores is the most amenable to smut control. All the commonly used seed disinfectants gave fairly good smut control with such seed. With seed bearing heavier spore-loads control was less effective, and the differences between the most and the least efficient disinfectants became much more pronounced. Whereas the mean percentage of smut in the fields sown with Ceresan-treated seed was 0.49, in the fields sown with formaldehyde-treated seed it was 2.20. Still more pronounced were the differences in the range of smut percentages after different seed treatments. The percentages of smut ranged from 0 to 42 in fields seeded with untreated seed, but in fields seeded with Ceresan, Leytosan, or formaldehyde-treated seed they were 0 to 9, 0 to 30.5, and 0 to 45, respectively.

The method of applying a seed disinfectant to the seed has a bearing on the effectiveness of smut control. It has been found* that seed-treating machines differ in respect to their efficiency in distributing seed disinfectants evenly over the seed. The most effective smut control is obtained by an even distribution of the disinfectant. The data presented in Table 4 seem to be in accord with the above conclusions. Seed treated by machine resulted, generally, in crops with less smut than that treated by shovel. Treatment with a machine, however, cannot always be relied on to give good smut control. For instance, it was found that one of the fields sown with seed that had been treated by machine with formaldehyde had 45 per cent smut.

* Unpublished data by W. Popp, Dominion Laboratory of Plant Pathology, Winnipeg, Man.

TABLE 4.—THE EFFECT OF METHODS OF APPLICATION OF SEED DISINFECTANTS ON THE PERCENTAGE OF SEEDLING-INFECTING SMUT DEVELOPING IN THE FIELD

Method of seed treatment	Number of fields examined and the mean percentage of smut after seed treatment						
	Ceresan		Leytosan		Formaldehyde		Mean
	No. of fields	% smut	No. of fields	% smut	No. of fields	% smut	
Machine	104	0.35	55	0.66	16	3.34[1]	0.72
Shovel or auger	35	0.41	40	1.08	73	1.90	1.32

[1] This figure is unduly high owing to the fact that one field contained 45% smut.

TABLE 5.—THE EFFECT OF STORAGE OF SEED TREATED WITH ORGANIC MERCURY DISINFECTANTS ON THE CONTROL OF COARSE GRAIN SEEDLING-INFECTING SMUT

Days of post-treatment storage	Number of fields examined and mean percentage of smut in the crops				
	Ceresan		Leytosan		Mean
	No. of fields	% smut	No. of fields	% smut	
1 – 3 days	48	0.68	35	1.60	1.07
4 or more days	91	0.19	60	0.39	0.27

Seed disinfectants available at the beginning of this century, such as copper sulphate and formaldehyde, were applied to the seed usually only a day or less before seeding. With a longer interval than this between treating and seeding, the grain, if kept moist, might sprout and, if allowed to dry, might be injured by these disinfectants (4, 5). Organic mercury compounds, on the other hand, give more effective control of seed-borne diseases if applied to the seed several days before seeding than if applied immediately before (5), and seed treated with them can be stored without risk of injury.

The foregoing observations were corroborated by data obtained during the seed-drill survey (Table 5). The effectiveness of Ceresan and Leytosan in controlling smut increased gradually with an increase in the number of days of post-treatment storage. The mean percentage of smut in the fields sown with seed that was treated one to three days before seeding was 1.07, as compared to 0.27 in the fields sown with seed treated four or more days before.

One of the most interesting results of the seed-drill survey is the reaction of different varieties to smut under ordinary farm conditions. The data summarized in Tables 6 and 7 show that the prevalence of smut varies considerably in different commonly grown varieties. Although, in

TABLE 6.—PERCENTAGES OF SMUT IN DIFFERENT VARIETIES OF OATS IN MANITOBA

Variety	No. of fields	Range in percentage	Mean percentage
Garry	10	0	0
Ajax	144	0 – 13.0	0.47
Gopher	10	0 – 3.0	0.51
Exeter	107	0 – 13.5	0.58
Anthony	8	0 – 6.0	1.94
Vanguard	86	0 – 29.0	2.30
Victory	6	0 – 14.0	3.04
Others	32	0 – 12.0	1.08

TABLE 7.—PERCENTAGES OF SMUTS IN DIFFERENT VARIETIES OF BARLEY IN MANITOBA

Variety	No. of fields	Percentages of seedling infecting smuts		Percentages of loose smut	
		Range	Mean	Range	Mean
Montcalm	132	0 – 8.7	0.46	0 – 18	4.28
Wisconsin 38	21	0 – 6.0	0.72	0 – 2	0.22
Garton's	45	0 – 12.5	1.20	0 – 7	1.44
O.A.C 21	124	0 – 21.0	2.68	0 – 10	1.45
Sanalta	40	0 – 13.0	2.69	0 – 18	4.77
Plush	78	0 – 45.0	6.33	0 – 17	2.73
Others	24	0 – 10.0	1.59	0 – 11	1.14

the compilation of data on the prevalence of smut in different varieties of oats and barley, no consideration was given to the spore-load and the kind and method of seed treatment, it is assumed that the average results for three years from all districts of Manitoba give a reliable smut index.

With the exception of Anthony oats, the extreme susceptibility of which is not indicated by the few fields examined during the survey, the data presented in Table 6 are in accord with the results of experimental tests on the varietal susceptibility of oats to smut.

The varieties Victory, Anthony, and Vanguard are highly susceptible to smut in experimental tests and, likewise, they showed high percentages of smut in farmers' fields. The varieties Gopher, Ajax, and Exeter, on the other hand, proved even more resistant in farmers' fields than experimental tests would indicate. No smut was found in any of the ten fields of Garry oats that were examined, although seed of this variety was ordinarily contaminated with spores. These spores may have been transported by the wind from neighbouring fields or have reached the seed by way of a combine that had previously harvested a smutty crop.

Similarly, varieties of barley that were susceptible to seedling-infecting smuts in experimental tests had considerably more smut in farmers' fields than the varieties that showed even slight resistance. As shown in Table 7, the varieties Montcalm and Wisconsin 38, both of which have slight resistance to covered and to false loose smut, had on the average less than one per cent of plants infected with these smuts as compared with nearly 3 per cent for the moderately susceptible varieties, O.A.C. 21 and Sanalta, and

over 6 per cent for the highly susceptible variety Plush. The prevalence of loose smut in barley, however, was not in close agreement with the results of experimental tests. Montcalm barley is susceptible to three out of ten loose smut races so far identified, and when artificially inoculated with a mixture of races, it usually develops only one-half as much smut as O.A.C. 21 or Plush; yet in farmers' fields it had an average of over 4 per cent loose smut as compared with 1.5 per cent and 2.7 per cent in the two latter varieties respectively. Wisconsin 38 is susceptible to more races and, when artificially inoculated with a mixture of races, it develops as much or more smut than Montcalm, but, under natural conditions, the former variety had an average of only 0.2 per cent smut. Apparently varieties, such as Wisconsin 38, O.A.C. 21, and Plush, in which pollination usually takes place before the heads emerge from the sheaths and in which the glumes do not open widely during antheses can escape to some extent infections by loose smut under natural conditions.

DISCUSSION

The seed-drill smut survey of coarse grains in Manitoba revealed a number of interesting and important points concerning the control of cereal smuts. Obviously, smut, particularly in oats and barley, still causes heavy losses despite the fact that adequate control measures are available. Farmers, apparently, have been slow to adopt the newer methods of seed treatment, either because of conservatism or on account of the discomfort that may be experienced in handling organic mercury compounds. Probably both of these factors have been responsible for delaying the general adoption of the most effective smut control methods. However that may be, the fact remains that farmers who treat their seed annually or at least frequently have seed with relatively light spore-loads, whereas those who do not treat their seed or treat it infrequently, have seed with heavy spore-loads and, as a result, experience much more difficulty in controlling smut even with organic mercury disinfectants.

The survey showed that copper sulphate (bluestone) and formaldehyde are not effective seed disinfectants under ordinary farm conditions. Furthermore, it is known that they sometimes cause seed injury. It appears, therefore, that the use of these chemicals for smut control is no longer to be recommended.

Of the two commonly used organic mercury disinfectants, Ceresan gave considerably better smut control than Leytosan (Tables 3 and 4), particularly with an uneven distribution of the disinfectant through the seed grain, such as is obtained with the shovel or loading auger method of application. Panogen gave very good smut control, but as observations on its use were limited to a single year (1949) and to a small number of fields, its effectiveness could not be properly evaluated. Although a liquid disinfectant, Panogen, on account of the fumes that it emits, appears to be not less irritating to the operator of a treating machine than the organic mercury dusts.

Good control of smut requires not only an effective seed disinfectant but also a satisfactory method of applying it. There was considerably more smut in fields sown with seed that had been treated with a shovel or loading

auger than in those sown with machine-treated seed (Table 4). Present-day treating machines, although much superior to the older types, do not distribute the disinfectant over the seed as thoroughly as is required to give the best smut control. If disinfectants of the slurry or liquid-dry type come into more general use and if machines for applying them satisfactorily are developed, seed treatment for smut control will become much more effective.

Another possible means of reducing losses from smuts in coarse grains would be through a more general use of smut-free Registered and Certified seed. As seed of these classes must meet high standards of purity and quality it might be expected to be relatively free from plant disease organisms. Data from the seed drill survey do not confirm this expectation. None of the samples of Registered and Certified seed collected in the three years was entirely free from smut spores and a high percentage of them carried light to heavy spore loads (Table 2). It would appear, therefore, that growers of high-class seed must pay more attention to smut control in their product if it is to be recommended in preference to ordinary seed as an effective means of reducing smut losses in the commercial crop. Unless Registered and Certified seed is practically free from smut it is likely, if sown untreated, to produce a crop with considerable smut in it.

The most economical and effective way of controlling smut in coarse grains is to grow resistant varieties. Even partially resistant varieties help to reduce smut losses, as is shown in Tables 6 and 7. Susceptible varieties, unless treated regularly and carefully, are likely to become heavily contaminated with smut. While it would be desirable to have a higher degree of resistance to the seedling-infecting smuts of coarse grains than is to be found in most of the varieties now being grown, it is still possible to keep smut infection in these varieties at a minimum by means of good seed treatment practices. Control of loose smut of barley presents a much more difficult problem. This smut infects the seed at the time of flowering and can be controlled only by the hot water treatment. As it is practicable to treat only relatively small quantities of seed with hot water, the control of loose smut in a susceptible variety has proved to be very difficult. But if loose-smut resistant varieties of barley could be developed, or if a simple and effective method of treatment could be found, losses from loose smut would be greatly reduced.

SUMMARY

A seed-drill survey of coarse grains made in Manitoba during the years 1947 to 1949 inclusive revealed that an average of only 47 per cent of the farmers treated seed of oats and barley, and about 13 per cent of these used older and less effective disinfectants. About 55 per cent of the farmers that treated seed used a treating machine; the others used the shovel, a loading auger, or other less effective methods of application. Farmers who treated seed of oats and barley with a machine had an average of 0.72 per cent smut in their fields whereas those that used other methods of application had an average of 1.32 per cent. Of the farmers who used organic mercury seed disinfectants, 35 per cent stored their treated seed three days or less before seeding it and 65 per cent allowed four days or more for post-treatment storage. The former had an average of 1.07 per cent smut and the latter only 0.27 per cent.

In general, farmers who treated their seed regularly and used the most effective seed disinfectants with proper methods of application had crops that were relatively free from smut. Seed from these crops carried very few spores and when it was treated smut infection was practically eliminated.

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